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The Editor
Western Union TECHNICAL REVIEW
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New York 13, N. Y.

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MR. JOHN H. HACKENBERG, a Senior Engineer, in the Facsimile Division, has been continuously engaged in facsimile research and development since 1934. He was one of the members of the research team formed at that time to investigate the possibilities of facsimile in the handling of telegraph traffic. He has been responsible for the development of numerous items of facsimile equipment including the vertical drum transmitter and the Letterfax transmitter. He holds 17 patents — 16 of which are in the facsimile field.

Mr. Hackenberg began his career with The Western Union Telegraph Company in 1928 as a member of the staff of Research Engineer where he engaged in transmission studies and the development of equipment for the measurement and mitigation of interference on ground return telegraph circuits.

He received his Electrical Engineering degree from Ohio State University. For many years he has actively participated in the work of the I.R.E. Technical Committee on Facsimile.

MR. FRED L. O'BRIEN, Senior Project Engineer in the Facsimile Division, joined Western Union in 1921 after receiving a degree of BS in EE from Carnegie Tech. He was assigned to the office of Research Engineer where he dealt with inductive coordination and other aspects of electrical interference to communication circuits. In 1934 he was assigned to a group which was formed to study facsimile for use in the Telegraph Company. His work since then has been in the field of facsimile. When the initial facsimile circuit was placed in operation between New York and Chicago in 1936 he covered the Chicago terminal. His work has included laboratory design of amplifiers, modulators, inverters, and studies of magnetic storage and retransmission of facsimile signals.

His most recent assignments have been in the field of applications of various types of recording papers.

Mr. O'Brien holds a Professional Engineering license in New York State and has seven patents in the field of facsimile.

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Printed in U. S. A.

F. A. HERMAN, Director of IDP Methods, Office of Vice President and Comptroller

Mechanized Inventory Control

Figure 1. IBM 305 RAMAC System

In its plans for a capital program designed to expand operated plant to meet new and enlarged service demands, it was soon evident to Western Union that modern mechanized procedures were necessary to accommodate the immense amount of record-keeping work associated with the material inventory and to promote material utilization. In November 1958, in collaboration with Robert Heller and Associates, Management Consultants, research was undertaken to convert an out-moded manual system into a modern material inventory control system, comprehending the use of electronic data processing techniques. The magnitude of the task is indicated by the fact that there are about 60,000 items in the inventory valued at about $20,000,000. The entire program, including continuing research on current problems and solutions by way of modified applications, reflects the joint efforts of a number of departments. The new system is operating effectively and while additional refinements and improvements are constantly made, the basic concepts have proven to be sound and profitable; in fact, the tremendous expansion of inventory load and complexity could not have been expeditiously controlled under former methods.

This paper discusses the new system.

The Problem

In the conduct of its public communications system and in providing Private Wire Service, the Western Union Telegraph Company operates five warehouses which supply material, apparatus and equipment as needed throughout its operation. These warehouses are located at Atlanta, Chicago, Dallas, Jersey City, San Francisco. In addition, assembly and repair shops are operated at each warehouse location and a manufacturing plant is in operation at Chattanooga.

Approximately 100,000 stock records were manually posted at the warehouses to control the material inventory. In an average month approximately 75,000 receipt and disbursement transactions, involving 40,000 items of material, are handled. None of the usual operations involving material forecasting, inventory control, purchasing or material accounting were previously mechanized. This need, plus the lack of centralized control, prevented the preparation of adequate and timely reports required by management.

The scope of the material control problem comprehended the following functions:

1. Requisitioning of material,
2. Control of inventory at five warehouses,
3. Warehouse operation and clerical procedures,
4. Recording material contracts with vendors,
5. Purchases and Purchasing Department procedures,
6. Payment of vendor invoices,
7. Accounting and billing.

The Solution

The problem of improving the material inventory control procedures, including the mechanization of the clerical work pertaining to the requisitioning, purchasing, accounting, billing and other material control record-keeping, was assigned to an Inter-Department Material Control Task Force under the guidance of the Office of the Vice President and Comptroller.

Based upon the data obtained from a survey of the manual operations which were sampled and analyzed, it was concluded that centralized control was practical and that the processing of data by means of electronic computer equipment was feasible.

In the research and development of this general concept, the Task Force recommended to management the following:

1. Revision of the requisitioning procedure to permit faster shipment of material,

2. The establishment of a Material Control Center at New York for the purpose of centralizing the control of all phases of the warehouse material inventory. The group to operate under the direction of the Vice President of Plant,

3. The establishment of a telegraphic communication system tieing together the five warehouses and the Chattanooga Works with the Material Control Center at New York,

4. The installation of an IBM Type 305 RAMAC (Random Access Method of Accounting Control) Electronic Computer in the System IDP Center at New York under the direction and control of the Office of the Vice President and Comptroller,

5. The establishment of standard material nomenclature for some 60,000 different items of material and the publication of a Material Nomenclature Catalog. The matter of "catalog pricing" was also to be researched and developed in this phase of the project.

6. Centralized purchasing under the direction of the General Purchasing Agent,

7. Centralized billing and accounting control to be comprehended in the Computer operation,

8. A staggered physical inventory system whereby warehouses would not be closed for the purpose of taking a physical count of the material.

On July 1, 1960, the first warehouse was successfully cut over to the new procedures and six months later, the cutover, of the Jersey City warehouse piece-part inventory, from manual to mechanized procedures was completed. The Inter-Department Material Control Task Force thus culminated eighteen months of planning, research and the development of many new concepts of mechanized procedures.

IDP Equipment

The IBM 305 RAMAC system, selected for controlling at the Home Office the material inventory of the five warehouses, consists of a series of machines designed to approach control and accounting on an in-line mechanized basis. This approach comprehends the use of a storage device that permits rapid access to any of several million characters of data comprising the material and accounting records. The IBM 305 RAMAC system installed included machine units illustrated in Figure 1.

The characteristics of the IBM 305 RAMAC lend themselves to centralized control. Its large storage capacity of 20,000,000 (two disk units) alpha-numeric digits allows for the storage of many data relating to our 60,000 catalog items, to whatever extent they may be stocked, at any of the five warehouses. For future growth, a third disk storage file can be added to the present system to provide an added capacity of 10,000,000 characters of data when needed. The random access feature, the arithmetic capability and program logic abilities of the machine permit programming of simple and complex decisions. The 305 System is demonstrated schematically in Figure 2.

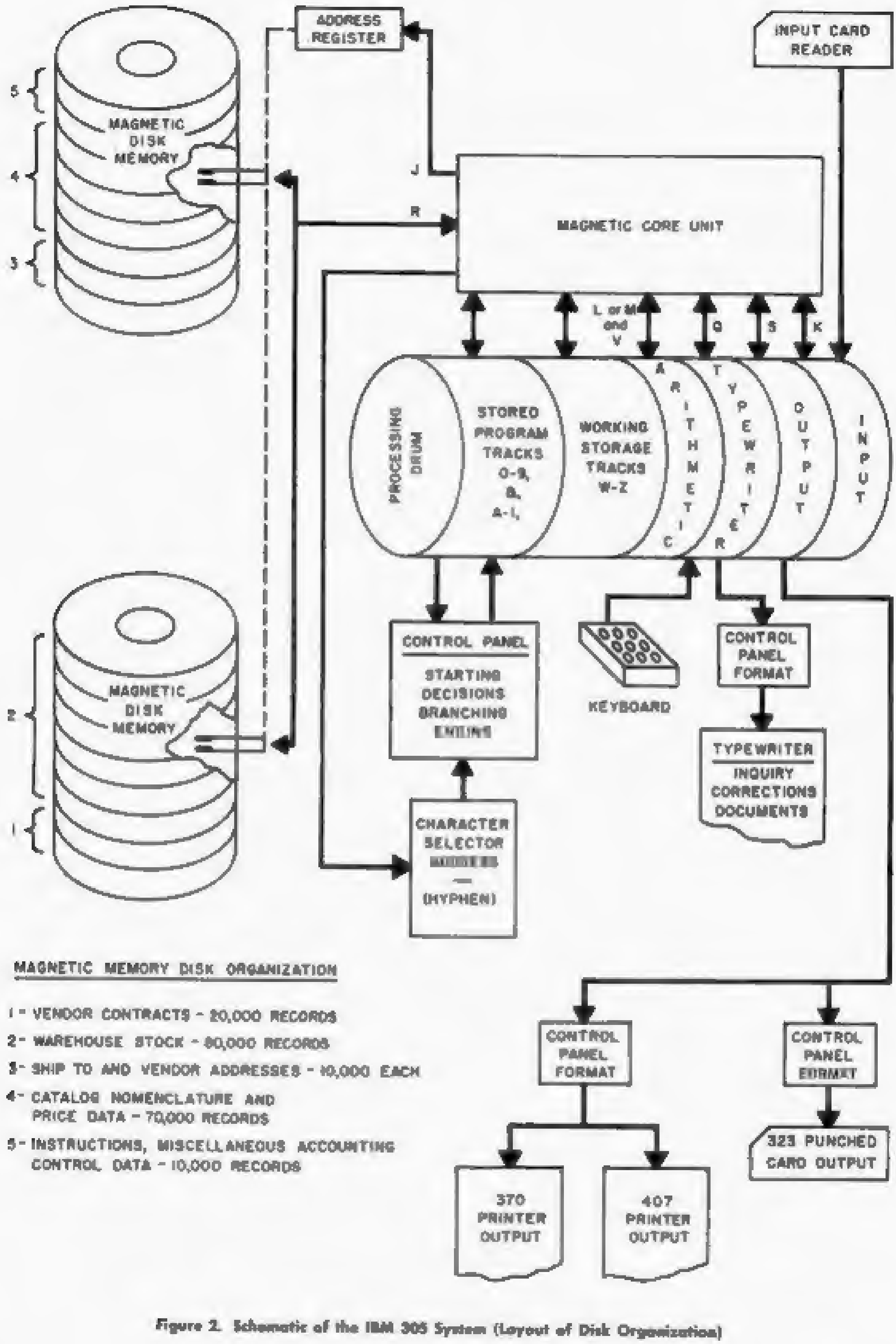


Figure 2. Schematic of the IBM 305 System (Layout of Disk Organization)

Storage Disk Organization

Each memory disk storage file is divided into 100,000 100-character addressable records. The assignment of records within the disk storage area is shown in Figure 2. The first five digits of the six-digit part number of each item contained in the Material Nomenclature Catalog is used as the index record address. The sixth digit of each part number is a figure devised from the first five digits by a mathematical formula and is used in computer programs to detect any errors in part number which may occur during clerical or mechanical preparation of input data. For example, material part number 123455 has its nomenclature index record stored at disk location 12345. The sixth (check) digit in this case is 5. Thus, for each piece of material listed in the nomenclature catalog, a 100-character nomenclature index record is maintained in storage. The layout of the nomenclature index disk record is shown in Figure 3 (a).

As some 58,000 items of material were stocked at the five warehouses, it was necessary to store this record at random in the second magnetic storage disk file. A chaining method was developed whereby the address of the warehouse stock record in the second file would be recorded in the 100-character nomenclature index record word in the first file. This chaining technique was necessary to conserve storage since like items were not, generally, stocked at all five warehouses. As a result, from a total possible require-

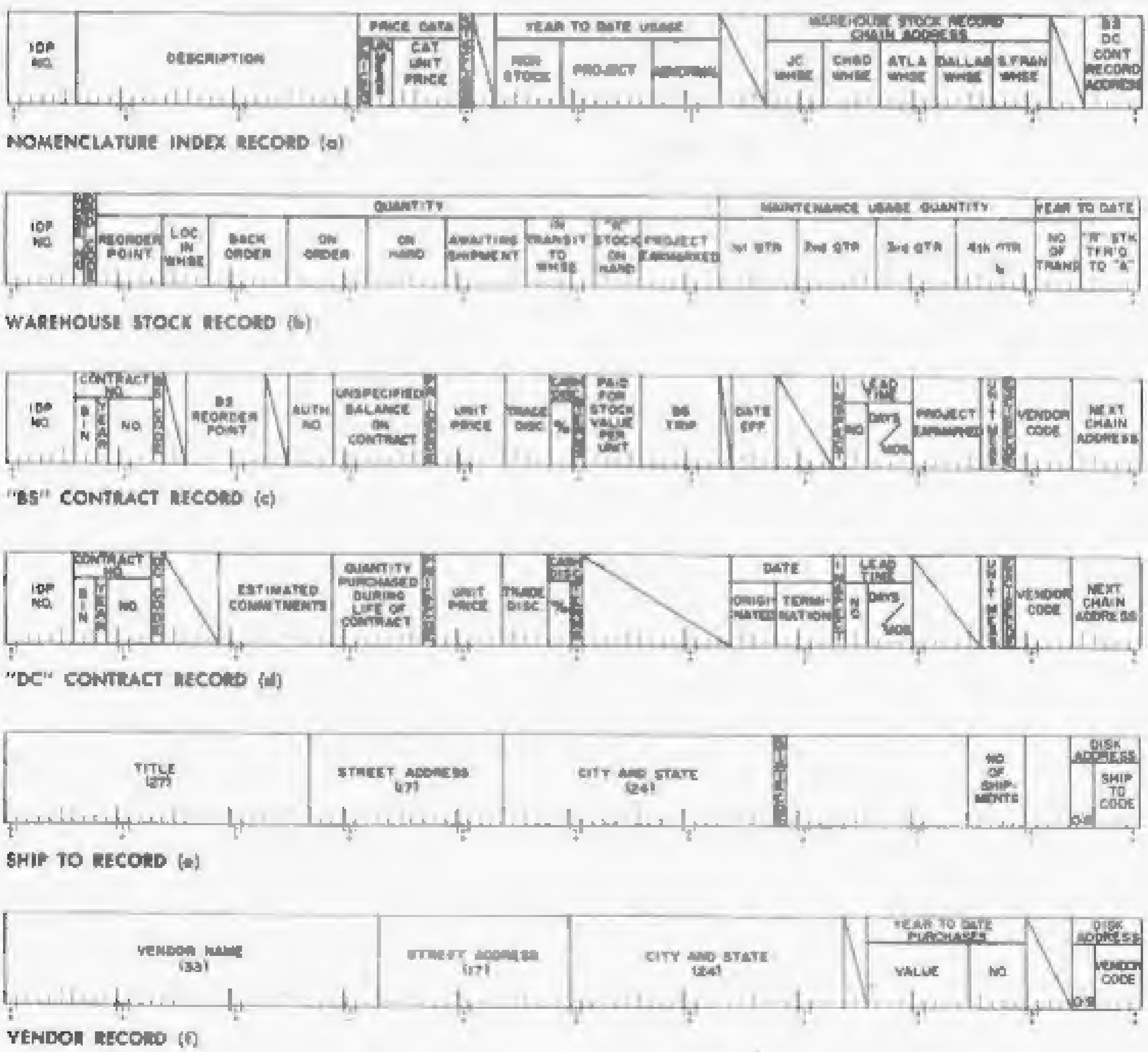


Figure 3. IBM 305 RAMAC Magnetic Memory Disk Layout (Address Location on Memory Disk)

ment of 300,000 stock records, the actual number of different items stocked at each warehouse is:

Jersey City	30,000
Chicago	12,000
Atlanta	5,000
Dallas	6,000
San Francisco	5,000
TOTAL	58,000

The layout of the warehouse stock record in the second disk unit is shown in Figure 3 (b).

In addition to the nomenclature index and warehouse stock records in the magnetic storage disk files, these files contain data such as Vendor Contracts, Vendor names and addresses, and Ship-To names and addresses. The layout of these records is shown in Figures 3(c) to 3(f).

The particular program instructions under which the 305 Computer processes input data are also stored in the disk file. Thus, as transactions are processed, a coded lead card calls out of memory the particular program instruction required for processing.

The Telegraph Equipment

The material control communication system links the five warehouses and the Chattanooga Works and the Material Control Center at New York. The telegraph equipment at New York consists of six Model 28 ASR sets connected to the line. Each ASR set is equipped with a Friction Feed Typing Unit, Keyboard Unit, Typing Reperforator and Transmitter Distributor. The special features on the ASR sets include vertical and horizontal tabulation, home copy suppression to suppress the punching of tape when transmitting, and a "calling" switch.

The equipment at the five warehouses and Chattanooga Works consists of a Type 19 set, a Type 7304 Selector and a Model 28 Receiving Only Teleprinter. The Type 19 set is equipped with a Friction Feed Typing Unit, Keyboard Unit and Distributor Transmitter. The Model 28 RO Teleprinter is equipped with a Sprocket Feed Typing Unit, vertical and horizontal tabulation, and a stunt box selector. Figure 4 shows the schematic circuit and equipment layout.

Form 475 Requisition

The requisition Form 475 is so designed that once the data is put into "machine language," all processing related to the items requisitioned will be generated by the computer using coded information from the original input cards with no need for re-submission of the requisition information. The Form 475 provides for input coding which establishes: tax liability; usage, i.e. purpose for which material will be used; warehouse code which normally serves the area in which the material will be used; accounting information; the Ship-To code number of the consignee; authorization number and date the material is required at destination. Additionally, the quantity required and IDP number (nomenclature part number) are listed. Basically, then, all data for all material transactions required to meet demands of field requisitions originate by the submission of a Form 475, (Figure 5).

Telegraphic Transmission of Data

After making a study of the equipment offered by various manufacturers, a type of adding machine, which incorporates a five-channel tape-punching mechanism (Figure 6), was selected as best suited to meet the requisites of data originating at the Warehouses and Chattanooga.

The so-called "add-punch" machine is programmed to insert automatically in the punched five-channel tape, codes to actuate the figures shift, carriage return and line feed functions in the telegraph printing equipment without conscious effort by the operator. This automatic programming also includes codes to control the action of the tape-to-card converter causing it to skip, duplicate, etc.

All forms used from which data are transmitted are designed so that data introduced into the machine are in specific fields not exceeding 8 digits. In the event

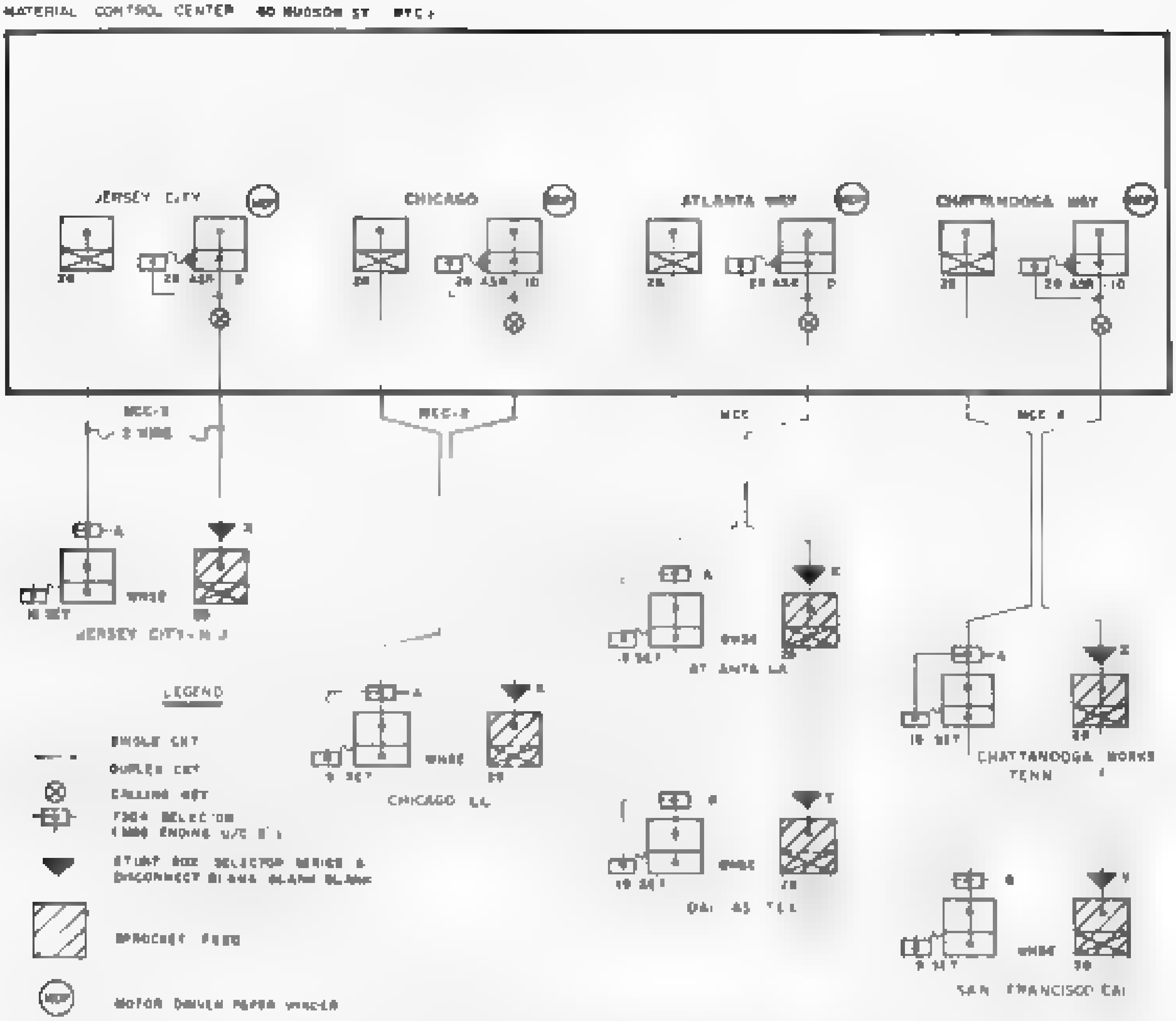


Figure 4. Material Communications Switching System Schematic

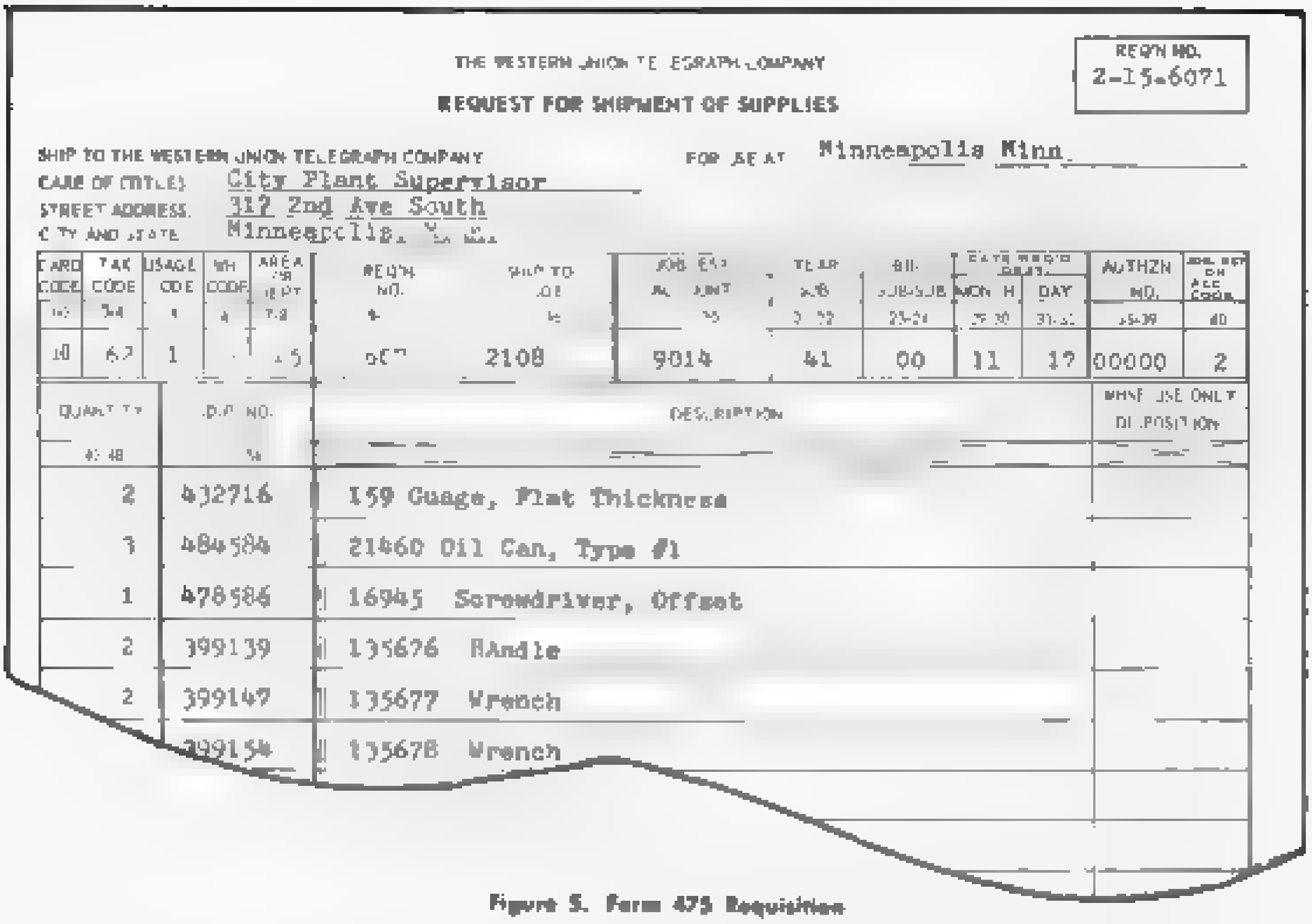
data fields having less than 8 digits are keyed into the machine, the add-punch is programmed to insert to the left of the keyed-in data, the required number of spaces necessary to fill an 8-digit field. To insure accuracy in transmission, the add-punch machine adds together the several 8-digit fields punched from each line of the source document and punches a "hash" total into the five-channel tape. Thus, for each line of data telegraphed there is a control total, which after conversion into punched cards, provides for a validity check of the telegraphic transmission by means of mechanically crossfooting the 8-digit fields.

Processing of Requisitions

Under the centralized material control concept, all requisitions for material must be processed by the IBM 305 RAMAC whether or not the material is stocked at a warehouse.

Upon reading a requisition card, the Computer proceeds to crossfoot the 8-digit fields and compare the total with the add-punch machine "hash" total. Should the first card of a requisition fail to crossfoot properly, the Computer is programmed to reject this card and any following cards having the same requisition number because the top line data are common to all items in the requisition. Several other preliminary programmed logic steps are taken in processing. For example, the computer is instructed, in effect, to obtain answers to questions such as:

1. Were the proper program processing instructions called out of memory?
2. Are the communication links between the control panels of each unit in the IBM 305 system operating properly?



THE WESTERN UNION TELEGRAPH COMPANY

REQUEST FOR SHIPMENT OF SUPPLIES

REQ'N NO. 2-15-6071

SHIP TO THE WESTERN UNION TELEGRAPH COMPANY — FOR USE AT Minneapolis Minn.

CARE OF (TITLE) City Plant Supervisor

STREET ADDRESS 312 2nd Ave South

CITY AND STATE Minneapolis, [illegible]

CARD CODE	TAX CODE	USAGE CODE	WH CODE	AREA OR DEPT	REQ'N NO.	SHIP TO	JOB EST AMOUNT	YEAR	SUB	SUB-SUB	DATE REQ'D MONTH	DAY	AUTHZN NO.	[illegible]
10	62	1	[illegible]	[illegible]5	[illegible]	2108	9014	41		00	11	17	00000	2

QUANTITY	IDP NO.	DESCRIPTION	WHSE USE ONLY DISPOSITION
2	432716	159 Guage, Flat Thickness	
3	484584	21460 Oil Can, Type #1	
1	478586	16945 Screwdriver, Offset	
2	399139	135676 HAndle	
2	399147	135677 Wrench	
	399154	135678 Wrench	

Figure 5. Form 475 Requisition

3. Do succeeding detail cards crossfoot correctly?
4. Is the input card code correct?
5. Are the account, usage and warehouse codes correct?
6. Is the IDP part number correct?
7. Is the quantity requisitioned excessive?

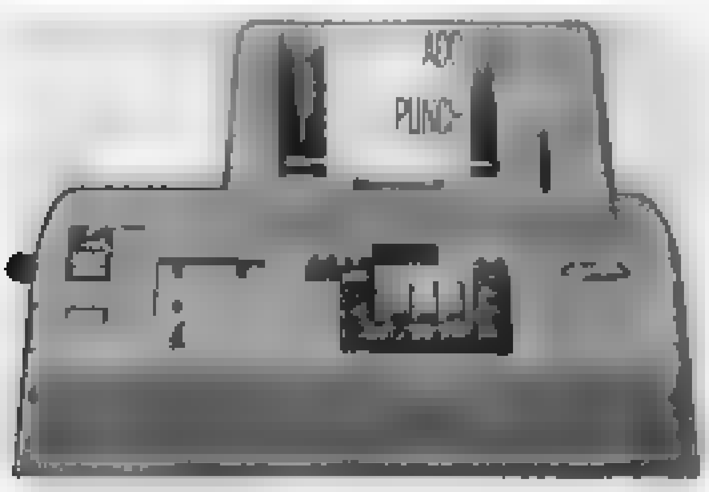
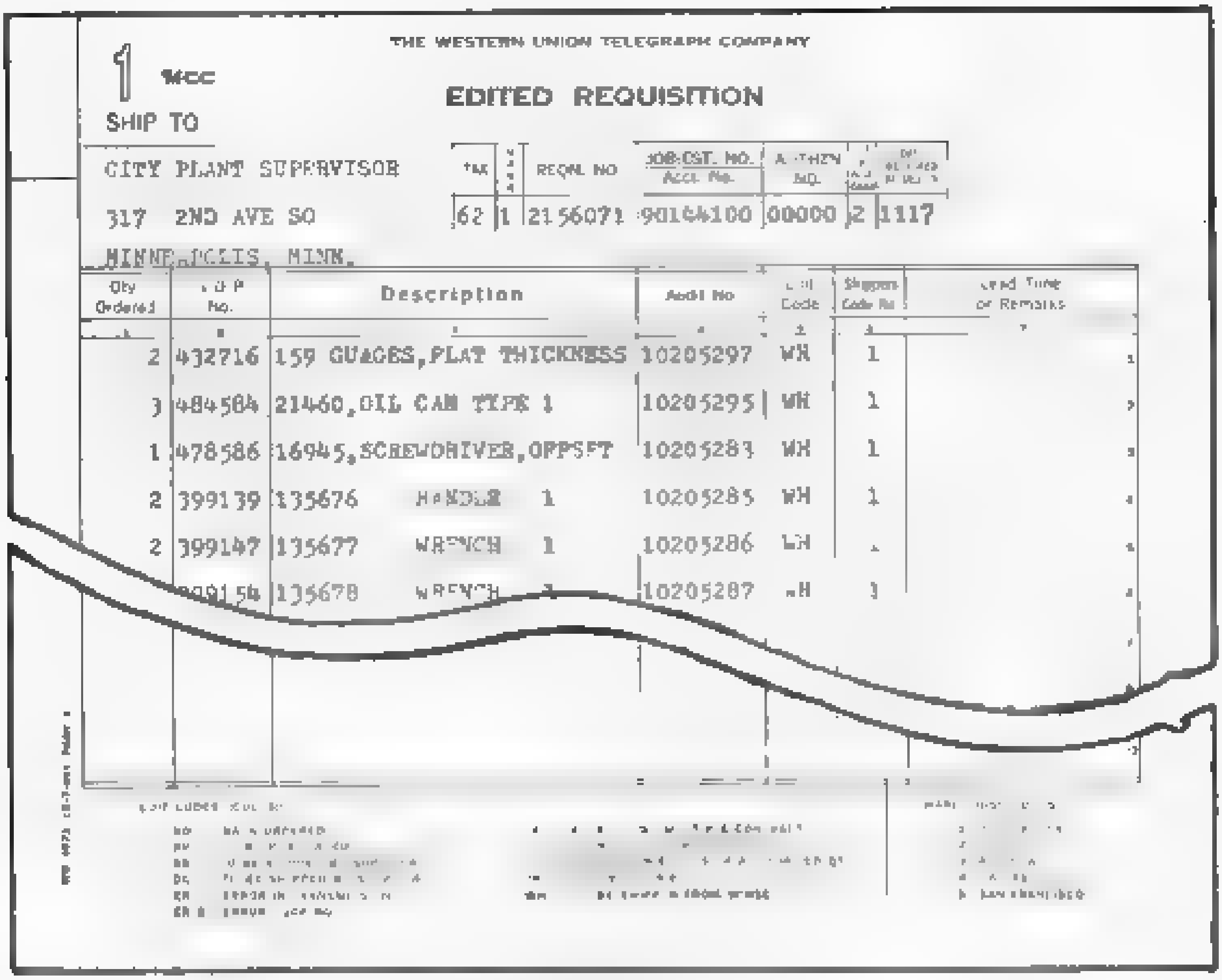


Figure 6. Add-Punch Machine

In the event any of the answers developed is negative, the program punches out an error card and prints a legend on the Edited Requisition, (Figure 7), indicating the type of error.

When the requisition card has passed the preliminary testing outlined above, processing proceeds as follows

1. For normal requisitions, the warehouse code in the requisition determines the priority chain of warehouses to be tested to fill the requisition. In the event the requisition quantity cannot be satisfied by the first warehouse of the chain, the second and third warehouses in the priority chain are likewise tested
2. Warehouse stock records are analyzed to test the quantity on hand for ability to fully or partially fill the requisitioned quantity. Where such quantity is not fully satisfied, a test is made of the on-order quantity. Should an on-order quantity exist, the quantity not filled from on-hand is placed on back-order. If there is insufficient quantity on-hand and on-order, the program will seek the next warehouse stock record in the normal chain for similar analysis.



THE WESTERN UNION TELEGRAPH COMPANY

1 WCC

EDITED REQUISITION

SHIP TO

CITY PLANT SUPERVISOR
317 2ND AVE SO
MINNEAPOLIS, MINN.

		REQN. NO.	JOB-CST. NO. Acct. No.			
62	1	2156071	90164100	00000	2	1117

Qty Ordered	No.	Description	Acct No	Code	Shipper Code No	Lead Time or Remarks
2	432716	159 GUAGES,FLAT THICKNESS	10205297	WH	1	
3	484584	21460,OIL CAN TYPE 1	10205295	WH	1	
1	478586	16945,SCREWDRIVER,OFFSET	10205283	WH	1	
2	399139	135676 HANDLE 1	10205285	WH	1	
2	399147	135677 WRENCH 1	10205286	WH		
	399154	135678 WRENCH	10205287	WH	1	

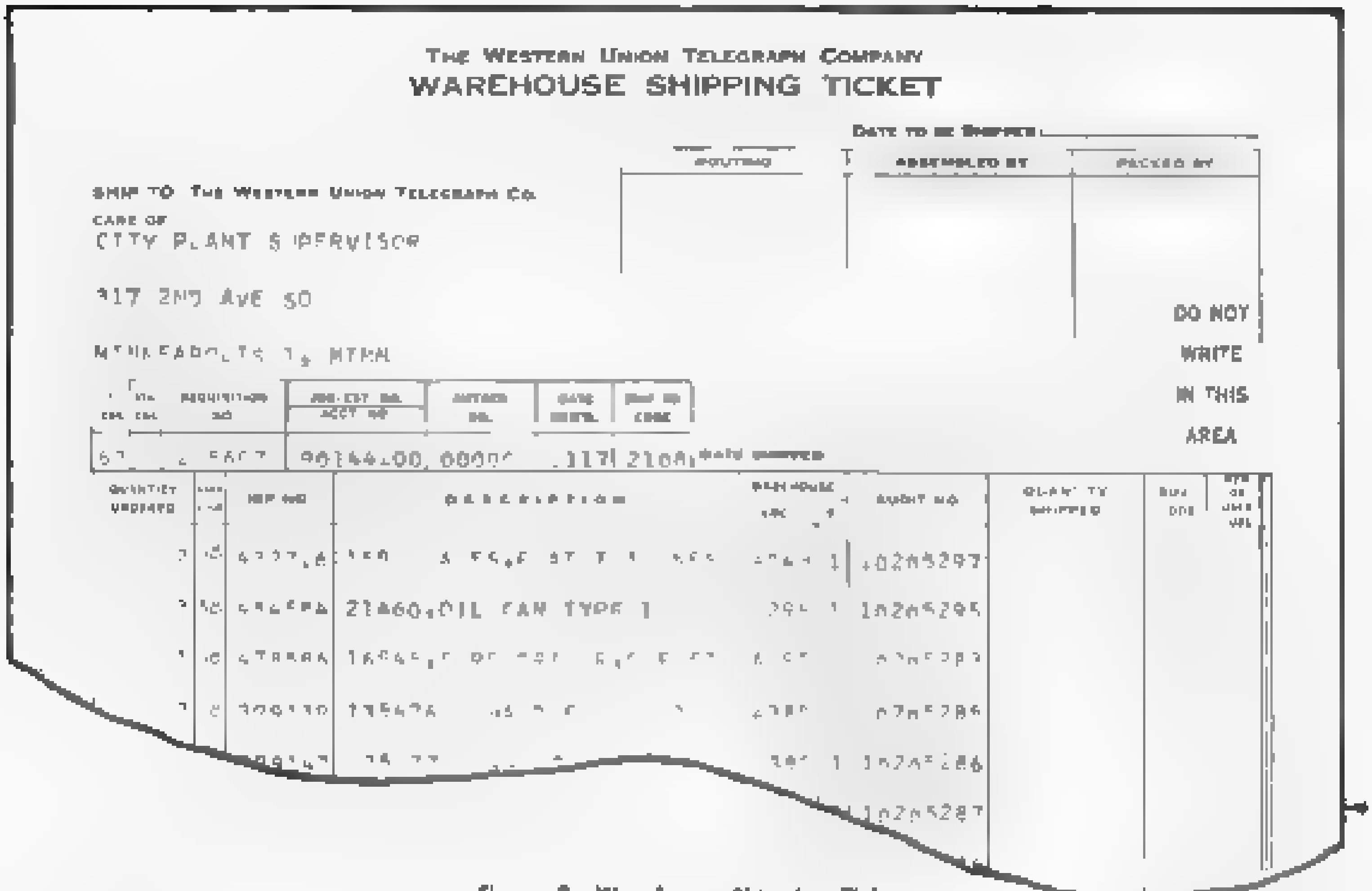
Figure 7. Edited Requisition

3. Where all the warehouses in the normal chain cannot fill or back-order the quantity requisitioned, the program will check the nomenclature index record for the presence of a contract. If so, the 305 is programmed to punch out a Vendor contract purchase card which is later processed to write a purchase order. If there is no contract, a so-called "blank purchase" card is punched out which is later processed to produce a register for the General Purchasing Agent.

4. When a requisitioned quantity is fully or partially filled, the IBM 305 Computer is programmed to reduce quantity on hand, increase quantity "awaiting shipment" accordingly and then punch out a warehouse shipping ticket card. If all or part of the quantity is back-ordered, the program updates the computer back-order record and punches out a back-order card. Prior to the end of the processing of a requisition card, usage data based upon usage codes are posted including the "number of transaction" record.

5. Whenever stock on hand is reduced by a requisition, the program tests whether the quantity on hand, plus quantity on order, less quantity back-ordered is equal to or less than the reorder point. Where such is the case, a reorder notice card is punched out. Whenever the quantity on hand reaches zero, an out-of-stock notice card is punched out. Promptly, therefore, reorder and out-of-stock notice cards are processed under another program to produce a Stock Status Report giving the stock record at all warehouses including contract data.

6. For every warehouse designated to ship material under a given requisition



THE WESTERN UNION TELEGRAPH COMPANY
WAREHOUSE SHIPPING TICKET

SHIP TO THE WESTERN UNION TELEGRAPH CO.
CARE OF
CITY PLANT SUPERVISOR
317 2ND AVE SO
MINNEAPOLIS 1, MINN

DO NOT WRITE IN THIS AREA

Figure 8. Warehouse Shipping Ticket

number, a set of header cards is punched out by the computer to provide shipping ticket Ship-To and top-line information. For every requisition processed, an edited requisition is produced on the 370 Printer showing the IBM 305 Computer disposition of each item processed.

Warehouse Shipping Tickets

After the processing of requisitions, the Computer output cards are promptly sorted and the Warehouse Shipping Ticket cards and associated header Ship-To cards for each warehouse are converted to 5-channel tape through the use of the Type IBM 063, Card-to-Tape Converter. As each warehouse shipping ticket card contains the location of the material in the warehouse, (this information is a part of the stock record in memory) the cards are sorted by location number to permit faster selection of the material by stock selectors.

When the 5-channel tape is transmitted to the appropriate warehouse, the telegraphed data is received on a Type 28 RO Teleprinter to produce a six-part Warehouse Shipping Ticket, (Figure 8)

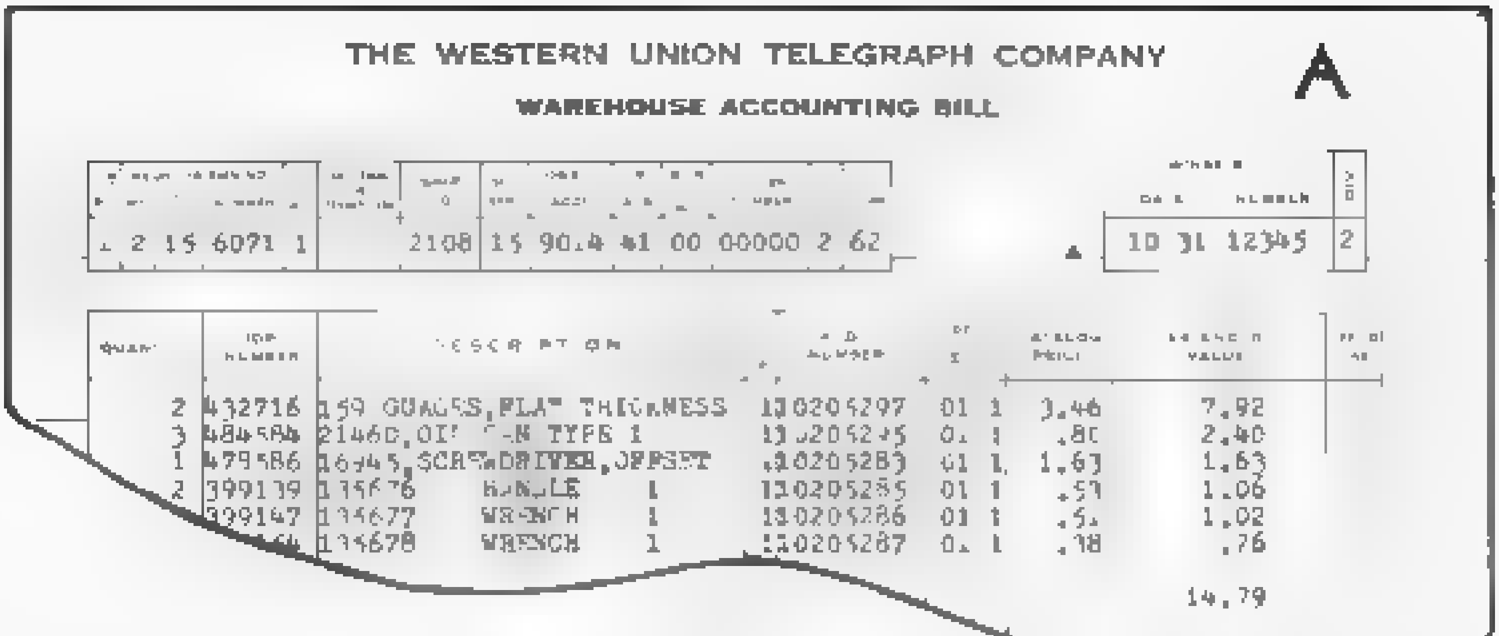
As the material is selected, the stock selector posts, the quantity selected on the Warehouse Shipping Ticket, whether the material was new or used and any applicable difference codes. After the material has been actually shipped, notification is telegraphed to the Material Control Center at New York.

Stock Disbursement Billing

The Notice-of-Shipment transmission tapes, as received at the Computer Center, are converted into punched cards and associated with the Warehouse Shipping Ticket cards which were originally transmitted to the warehouses. The Warehouse Shipping Ticket cards and associated shipping notice cards containing the quantities actually shipped and billable are combined for processing the stock disbursement billing. (Figure 9).

Material Purchases

Requisitioned items designated for purchase and stocked items scheduled for replenishment are processed through the RAMAC to prepare purchase orders. The



THE WESTERN UNION TELEGRAPH COMPANY

A

WAREHOUSE ACCOUNTING BILL

1 2 15 6071 1 | 2108 | 15 90.4 41 00 00000 2 62

10 31 12345 | 2

QUANT.	IDP NUMBER	DESCRIPTION			NUMBER			PRICE	VALUE
2	432716	159 GUAGES,FLAT THICKNESS			110205297	01	1	3.46	7.92
3	484584	2146D,OIL CAN TYPE 1			110205245	01	1	.80	2.40
1	479586	16945,SCREWDRIVER,OFFSET			110205283	01	1	1.63	1.63
2	399139	135676	HANDLE	1	110205285	01	1	.53	1.06
	399147	135677	WRENCH	1	110205286	01	1	.51	1.02
	[illegible]	135678	WRENCH	1	110205287	01	1	.38	.76
									14.79

Figure 9. Warehouse bill

purchase orders may be placed on vendor contracts or, if a contract has not been established for an item, the purchase is individually negotiated by the Purchasing Department with the vendor offering the most advantageous price, terms and delivery date.

Purchase contracts provide an economical and convenient means of setting up procurement channels for frequently used materials. Such contracts permit advantageous price negotiations, lend quality standardization to materials so purchased and save considerable time and expense in the preparation of purchase orders. For each contractual item there is a RAMAC stored contract record containing all the information necessary to prepare purchase orders entirely within the Computer. In the absence of contracts, vendor codes, prices and terms for each item are, after negotiation, prepared in punched card format, to supply the necessary information for the Computer

The Western Union Telegraph Company uses 1200 contract records to write 24,000 contractual purchase orders per year. This comprises one fourth of the total purchase orders written.

Routing, expected delivery date and other details peculiar to each individual order are manually written on the purchase orders by the Purchasing Department before release.

Purchase orders placed for the purpose of filling requisitions for items not in warehouse stocks are accounted for on the basis of mechanically processed invoice payments to vendors. This is accomplished by submission of accounts payable documents by the Purchasing Department to the Computer Center in a form readily translatable into IDP machine language. From these data, accounting bills are rendered to field projects or accounts. also purchase status cards are updated to furnish data for reports of open items and completed purchases.

Receipts of material purchased from vendors for the purpose of replenishing warehouse stocks are reported from receiving warehouses by means of five-channel perforated tape wire transmissions. The perforated tape is converted to punched cards which are then processed to update RAMAC "on-hand" balances, reduce "on-order" balances and to produce warehouse accounting bills detailing the individual charges. Purchase status cards are simultaneously updated for reports of open items and completed purchases.

Invoices for "into-warehouse-stock" purchases are forwarded from the Purchasing Department to the Computer Center and are processed for accounts payable disbursements. Invoice detail information also furnishes data for reports of open items and completed purchases. These status reports categorize the quantity invoiced in relation to the quantity received and ordered to insure compliance with the order and to verify final equality of quantities paid for and received.

Returns of Material To Warehouses

Returns of material from field locations to warehouse stock are reported to the Computer Center upon receipt at destination warehouses in a manner similar to that of reporting the receipt of purchased items. This information is processed in the RAMAC to produce warehouse accounting bills crediting field projects and accounts and charging the warehouse stock account. In the event that the returned items are in need of repair or otherwise unsuited to immediate re-use, they are classified as "Repair Stock" so as to be excluded from availability.

Accounting For Material Transactions

Accounting for computer-controlled material transactions falls into three major areas:

1. Field and Stock account billing;
2. Accounts Payable;
3. Inventory revaluations.

Material transactions in the form of (1) filling requisitions from warehouse stocks; (2) purchases of materials for stocks; (3) inventory adjustments; (4) field returns of material and (5) purchases of materials for field locations, comprise the types of material movement accounted for through billing. Each of these billing categories is identified by means of a bill-type code which prescribes the accounting procedure to be taken regarding the punched card billing records. These billing cards are condensed into summary cards for field charges and credits and offsetting accounts payable and warehouse stock charges and credits.

Under the mechanized accounting procedures, accounts payable are cleared through the Price Variation Account to convert purchase costs to catalog values. The converted catalog values of purchases are further cleared to billing accounts through a Material-In-Transit From Vendors account with the balance of material in transit detailed in a monthly open item report which represents the catalog value differential between items invoiced and received.

Since the Computer system of pricing appraises billing and stock balances at catalog prices, any changes in these prices require that a programmed revaluation of stock be made. The net changes in stock values calculated by the Computer are automatically applied to the stock account balances.

Each month the RAMAC prepares an inventory balance report showing the value of stock at each of the warehouses. These balances are proved by applying billing and price change revaluations to the prior month balances.

Management Reports

Having a record of material transactions in punched cards and having 20,000,000 characters of current data in the IBM 305 RAMAC Computer makes it possible to produce timely and better reports for management, such as the following:

Warehouse Stock Status Reports (daily upon demand),
Weekly Physical Inventory Reports,
Monthly Inventory Balance Reports,
Monthly Report of New Contracts,
Monthly Report of Current Purchases,
Monthly Report of Expired Contracts,
Monthly Report of Material Transactions,
Monthly Report of State Sale and Use Taxes,
Monthly On-Order—Back-Order Report,
Monthly Status of Accounts Payable,
Monthly Accounting Control Reports,
Quarterly Forecast of Material Requirements,
Annual Usage Report.

Advantages of the IDP System

After operation for one year under the centralized control concept, the following advantages were realized:

1. Better and more timely reports for management,
2. Faster processing of field requisitions,
3. Increased revenues through improved control of PWS project material,
4. Improved purchasing practices,
5. Improved accounting and budgetary control,
6. Staggered physical inventory practices,
7. Catalog pricing of material.

Inter-Department Task Force

The magnitude of the material control project was such that its success could only be realized through the coordination and cooperation of all department heads and a task group consisting of their appointed representatives. Those who served on the task force and contributed to the formulation of the centralized control concept were

COMPTROLLER'S DEPARTMENT

F. C. Boone, Methods Supervisor;

W. E. Ennis, General Accountant — Eastern Division,

W. F. Gregory, Division Comptroller — Southern Division,

A. E. Gumbs, General Accountant — Pacific Division;

F A. Herman, Director, IDP Methods;

H. G. Ruckert, General Accountant — Southern Division

B. E. Thompson, Supervisor, Material Accounting Bureau;

W. J. Walsh, General Supervisor, IDP Methods

INDUSTRIAL ENGINEERING DEPARTMENT

E. C. Novak, Methods Supervisor

C. A. Erickson, Senior Industrial Engineer

R. H. Holland, Manager, Standards and Controls (Operating)

PLANT DEPARTMENT

W K. Breeding, Manager, San Francisco Warehouse;

F. F Coffin, Manager, Material Control Center;

D. Fero, General Supervisor, Forecasted Material,

F. L. Hannon, Assistant to Manager Forecasted Material,

S. Jack, Manager, Jersey City Warehouse;

M. F. Nehemiah, Assistant Manager, Material Control Center;

J. H. Weems, Program Manager — Telex Program.

PURCHASING DEPARTMENT

L. P. Demontreaux, General Supervisor, Material Procurement;

J. A. LaCas, Assistant General Purchasing Agent,

J. F. Marshall, Buyer;

W. M McCormick, Buyer.

Frank A. Herman is Director of IDP Methods, reporting to the Assistant Comptroller—Methods and Procedures. His responsibilities comprehend the research, development and maintenance of all computer programs and IDP methods required in the operation of the Division IDP Centers located at Atlanta, Chicago, Dallas and San Francisco and the System IDP Center and the Material Control Computer Center located at Headquarters. In 1954 he transferred from the Operating Department where he held the position of Division Administrative Manager, Metropolitan Division, to the newly organized IDP Methods and Procedures Bureau of the Comptroller's Department. After several years in methods research and development work associated with integrated data processing he was assigned to direct the development of the material control procedures and computer programs for the Material Control Computer Center

F. T. TURNER, Senior Project Engineer

Character Recognition Systems

In recent years industry has shown great interest in the development of machines which will "read" printed or typed copy There is great need for such devices as input to computers and business data processors. An example of the latter, now in existence, is a machine which sorts checks and reads the account number printed on each check. The number is printed in a magnetic ink, and the information from the copy is obtained by a magnetic pickup head.

While this device is of great value in its intended field of application, its use is somewhat restricted. A number of firms have reading machines with more general applicability under development. Few of these have progressed to the "hardware" point. The basic concepts behind the approaches have usually led to devices of considerable complexity with resulting high cost. This has tended to restrict their application to situations where a very large volume of material is to be processed. Fortunately, this is facilitated by the fact that the circuitry is usually suitable for high speed operation

Need for Moderate-Speed Equipment

There are in the field of Western Union's operations a number of applications where a reading machine which can operate at speeds of the order of 100 to 200 words per minute can find ready application. In many locations the high volume required to justify the use of one of the high speed reading machines simply does not exist. A moderate-speed, moderate-cost machine would provide much-needed flexibility

Western Union, at its laboratory at Water Mill, is actively engaged in the development of such a reading machine for general application It is expected to operate at a speed in the order of 150 words per minute. Its output will probably be in the form of punched tape, although it appears possible to connect it directly to existing automatic switching equipment.

A number of problems must be solved in the course of its development, for example: the physical handling of the copy, correcting for skewed or misaligned type, action to be taken in the case of an unreadable character, etc., to name but a few

Development

Some of the existing equipment handles the copy flat. In many cases the image of each letter is dissected by a miniature scanning raster similar to a television scan. The resulting signal is processed for recognition of the letter by logic circuitry of various orders of complexity.

In the Western Union Automatic Reader now under development, the copy is automatically wrapped on a drum and scanned as in a facsimile transmitter. Unlike the facsimile transmitter, however, the copy is not scanned by elemental areas. Instead the scanning system projects an image of each letter in turn on a field of photocells. Each different letter or symbol will cover a unique group of photocells, and any character may be recognized by noting the output of a properly selected set of cells unique for that character

Photocell Selection

It might appear that the simplest approach would be simply to note the cells covered by a given character, and subsequently in the reading process to assume that these same cells will be covered if this character appears on the field. Such an approach is simple in concept but is unsatisfactory from a practical standpoint For example, some characters cover nearly 40 cells, and the circuitry would be undesirably complex if all the cells were used in such cases.

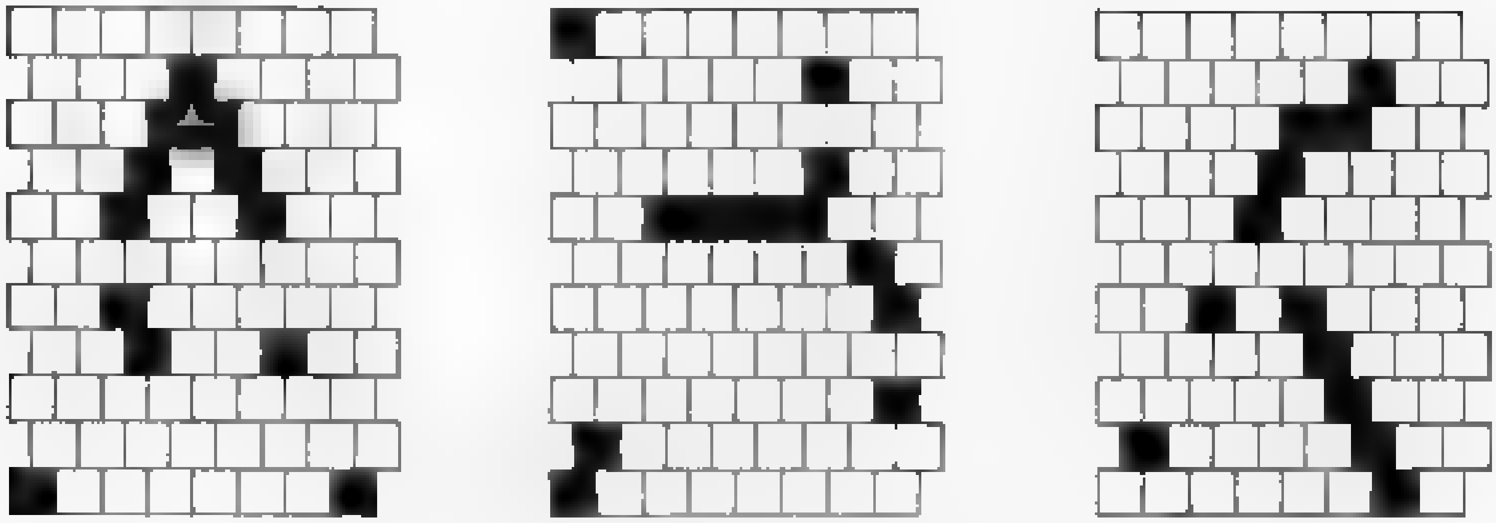


Figure 1 "Yes" Cells for A, B and K

A more rational design results if a reasonable number of cells is used. This number is preferably the same for each character No rigid rules are laid down for the choice of this number, but many factors are to be considered

The type font selected for use in this equipment has a total of 60 characters. If these characters had an ideal form, and could be assumed to be always perfect, no more than six cells would be required for any character. (Two raised to the 6th power equals 64) In practice, however, the characters do not have an ideal form and they may be imperfectly printed. It is also desirable that the number of cells be chosen so as to provide some degree of redundancy; i.e., to allow for the possibility that all selected cells may not be fully covered even though the relevant character is on the field. Twelve cells were chosen as the number for the Western Union Automatic Reader

Magnitude of Problem

When twenty, thirty, or more cells are available to choose from, selection of the best twelve presents some interesting problems. The number of possible combinations of 30 cells, taken twelve at a time, is of the order of 86 million. To try each of these in turn and then select the best combination would obviously be beyond the capability of any ordinary development team. This is especially true if it must be done for a large number of characters.

In the early stages of the development it was assumed that it would be sufficient to distribute the cells more or less uniformly over the outline of the letter. This was soon found to be unsatisfactory, as it did not take into account the fact that a large number of letters share a common element, such as the left hand vertical bar in the letters B, D, E, F, H, K, L, M, N, P, etc. The cells must be placed in those

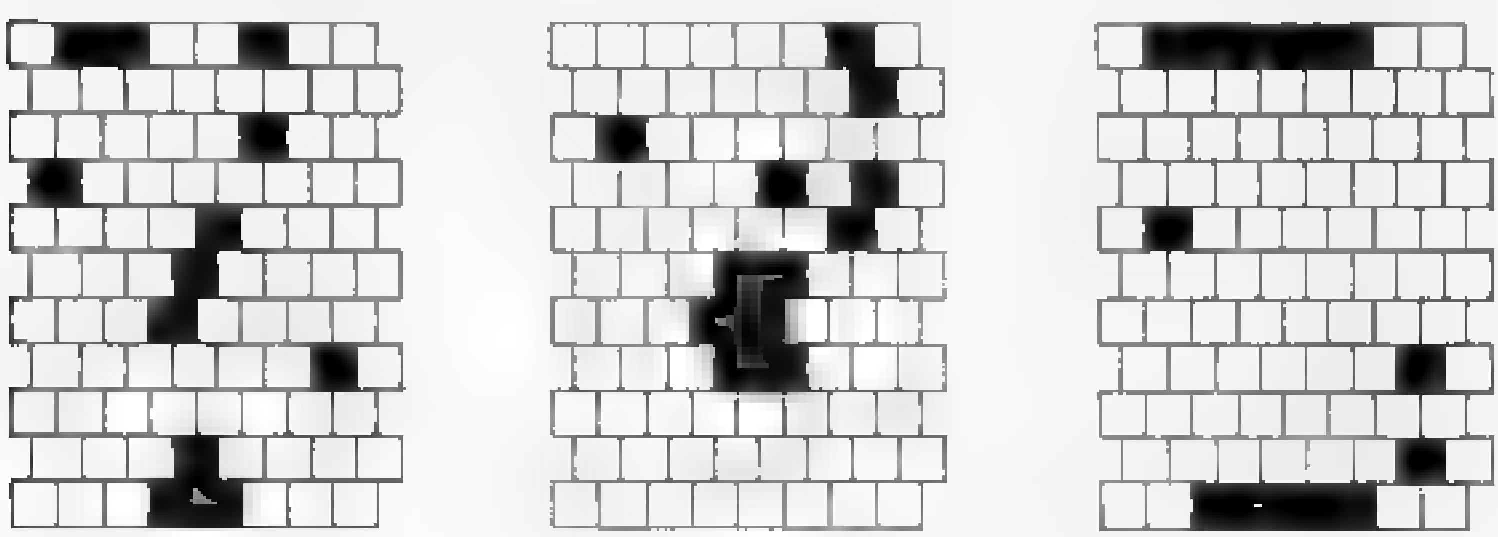


Figure 2 "No" Cells for A, B and K

portions of the letter which are the most significant. Because the significant portions of a letter are not always readily apparent, a great deal of time might be consumed in making these selections.

Formal Approach

By preparing an enlarged overlay with the positions of the cells marked thereon and superimposing this overlay on enlarged drawings of the letters, lists of the cells covered by each letter were prepared. By comparing the list for one character with that for another, the extent to which the two characters resembled each other could be assigned a numerical value by counting the number of cells common to both lists. This indicated the extent to which an image of one letter might give a false indication on cells chosen for the other. With this value available, it was then possible to assign a number to each cell which bore a negative relationship to the value of this cell for recognizing a given letter.

When these numbers were obtained for all cells with respect to each letter, it was then possible to obtain for each letter an order of preference for the cells covered by that letter. From this list the twelve best cells could be chosen. Figure 1 shows the locations of cells so chosen for the letters A, B and K. It is interesting to observe that the pattern of cells emphasizes some portions of the letters while ignoring others. In some cases the letter represented might not be readily recognizable. Study of the cells selected for a number of letters shows that those portions of a letter which are common to many letters are generally avoided, and the selected cells are concentrated in the distinctive portions of the letter.

Computer Aids in Selection

The operations necessary to obtain the order of preference for the cells were performed manually for a few characters, using a succession of tables and check lists. The manual operation, while perfectly practical, was still somewhat time-consuming. It was estimated that approximately thirty working days would be required to develop preferred order lists for 60 characters. This is expensive and time-consuming. It appeared that the problem might be solved by a computer, such as the IBM 650 (RAMAC) and other computer equipment in the New York headquarters.

The computer approach was found to be feasible and a program was written. The problem was run off and the lists obtained, at a cost, including programming of about 25 percent of that estimated for the manual operation.

Yes and No Cells

At an early stage in the development it was recognized that it would be extremely difficult to distinguish between certain pairs of letters such as C and G, O and Q and several others. Accordingly, the concept of associating with each letter an additional group of cells, (which would not be covered if the said letter was on the field) was developed. The first set of cells, and this latter set, are referred to as "yes" and "no" cells respectively.

The number of "no" cells was chosen the same as the number of "yes" cells primarily for circuit considerations. During the early "cut and try" period, "no" cells were connected when required, by observation of apparatus performance, to reduce the interference produced by letters similar to the letter under consideration. Again, this proved to be a slow process and did not necessarily lead directly to the most effective application of the cells.

Manual processing of the cell lists in a manner similar to that employed for the "yes" cells proved more efficient. After the success of the computer approach was demonstrated for the "yes" cells, a modification of the "yes" program was developed and applied for selection of the "no" cells. Figure 2 shows the "no" cells for the letters A, B, and K.

It has not been possible to reliably establish that the cell selection techniques discussed above lead to the best possible set of cells. It appears that here are probably a number of possable sets, differing by only one cell, that will be almost indistinguishable on the basis of performance.

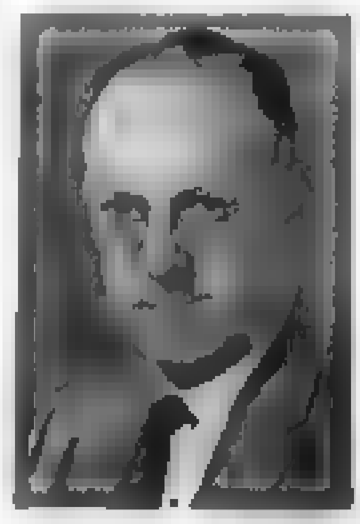
We can be fairly certain, however, that the technique at least leads us to some one of a group of good selections. The selections for several letters have been tested and found to give good discrimination. Efforts have been made to improve on the selections by changing a few cells but no gain was obtainable in any reasonable number of trials.

It should be pointed out that this paper represents an interim report, and the reading machine is not yet complete. However, developmental models, working with a type face different from the present design and having a smaller number of characters, have demonstrated the feasibility of the basic approach

* * * * *

Acknowledgments

The author is indebted to Mr F A Herman and Mr. D. J. Connors of the Comptroller's staff, the former for advice and assistance and the latter for the actual writing and running of the computer program.



Mr. Frank T Turner is Senior Project Engineer with the Electronics Research Division at Water Mill, Long Island. He has been active in the development of facsimile equipment, a transistorized radio teletype converter, the Plan 37 switching system and the 210-A Bomb Alarm System. He entered the employ of Western Union in March 1946, having previously gained wide experience in the field of facsimile He was employed in design and production of facsimile apparatus by International News Photos In World War II he spent 18 months in Europe in the Air Force supervising installation operation and maintenance of facsimile networks and equipment His work in this field contributed to the present national Weather Map Facsimile network

Mr Turner was a member of the IRE Technical Committee on Facsimile. He is a member of the Institute of Radio Engineers and the American Mathematical Society

Editorial Note

Although the prototype machine was designed to read telegrams received by telephone and to transcribe them into punched tape form to be fed into the automatic switching system, this machine is anticipated to have many and varied applications

R. P. ROMANELLI, Ass't. to Ocean Cable Plant Supvr., Int'l. Comm.

Trends in Cable Ship Design

The submarine cable world salutes a fleet of new cable ships: a cable repair ship and two cable layers for British owners, a cable layer for American owners, a cable layer for the French, two cable layers for the Russians, a cable layer-bulk carrier for the Germans, and a cable repair ship-icebreaker for the Canadians.

Rarely has there been such a rapid appearance of wide variety of cable ship tonnage. The reason for this can be attributed to the fact that the laying of thousands of miles of new cable in the past few years and the planning of many more thousands of miles of cable over new routes has been accompanied by the rapid obsolescence of some of the famous old cable ships whose names have long been symbols of the fascinating story of submarine cables. Thus, with the approaching twilight of the illustrious ships of the past and the birth of the new leaders of the future, it is appropriate that we examine some of the recent trends in the art.

Types

CABLE SHIPS are commonly classified according to their primary function as either cable repair ships or cable laying ships. The former type usually is smaller, more maneuverable, of shallow draft, and designed to handle cable over the bow almost exclusively. Examples of cable repair ships are Western Union's C.S. LORD KELVIN, built in 1916 and Cable and Wireless' new C.S. RETRIEVER, built in 1961, as shown in Figures 1 and 2. On the other hand, cable laying ships are larger ships, usually capable of carrying a sufficient amount of cable for laying the complete, deep-water portion of a transatlantic section, about 1800 nautical miles. The design requirements of a cable repair ship cannot easily, if at all, be reconciled with the requirements of a cable layer. Thus, an attempt to combine the features of both types only serves to add further to the conflicting demands in any ship design. The particulars of some of the new and old cable ships are compared in Table I.

Figure 1 C.S. LORD KELVIN, built 1916

Courtesy of Cable & Wireless Ltd

Figure 2. C.S. RETRIEVER, built 1961

It may be helpful at this point to explain the word "tonnage" in Table I as used to indicate size of vessel. A designation of tonnage could indicate either weight or volume depending upon whether it is gross, or deadweight.

Gross tonnage—A measure of the internal volume of the ship at 100 cubic feet per ton.

Deadweight tonnage—A measure of the weight of all the consumables, such as cargo, fuel, cable, water and stores at 2240 pounds per ton.

Hull Form and Size

Just as length is an essential factor in the non-dimensional Reynolds number which is so important in the study of fluid flow, so the length of the ship, when related to the speed, in the naval architect's familiar speed-length ratio:

$$\frac{V}{\sqrt{L}} \quad \begin{array}{l} \text{where } V = \text{speed (in knots)} \\ L = \text{length (in feet)} \end{array}$$

becomes the fundamental parameter for hull size and speed.

The speed-length ratios of some cable ships are given in Table I. The recent increase in ratio reflects the universal trend for greater speed which has been produced to meet modern requirements and to reduce the cost of operation. Although fuel costs rise rapidly with speed, crew wages still represents a major element of cost. In the 1920's and 1930's an A.B. seaman in Canada was paid $65 per month while today his salary is over five times that amount.

As the speed-length ratio increases it is necessary to develop finer hull lines so as to keep the wave-making and other elements of residuary resistance to a minimum. The higher speeds realized with a finer hull result in greater frictional resistance which can be expressed as follows:

$$R_f = f\,S\,V^{1.854}$$

where f = a constant

S = the wetted surface area of the underwater portion of the hull (in square feet)

V = ship speed (in knots)

R_f = frictional resistance (in pounds)

However, the increase in frictional resistance is less than the increase in residuary resistance, which, at relatively higher speeds, constitutes the principal component of resistance.

The selection of a suitable length presents one of the most involved compromises in the art. In addition to being so

TABLE I

CABLE SHIP DATA

			Length					Net Cable Capacity	Tonnage				
	Built	Company	Overall	B P	Breadth	Depth	Draft	Cubic ft	Gross	Deadweight	Main Propulsion	Speed Knots	Speed Length Ratio
Pre-War Ships													
LORD KELVIN	1916	Western Union	332'9"	300'0"	41'0"	25'0"	22'3"	32 100	2,641	2 900	Recip. Steam	12	.69
CYRUS FIELD	1924	Western Union	237'7"	211 0	34'0"	18'6"	17'2"	7 443	1,288	1,022	Recip Steam	10	.69
Post-War Ships													
RETRIEVER	1961	Cable & Wireless, Ltd.	368'	330	47'6"	29'6"	19'0"	21,000	4,000	2 750	Diesel-Electric	15	.83
ALERT	1961	British Post Office	418'	375	54'6"	33'3"	22'6"	57,000	6,200	4,600	Diesel-Electric	15	.78
MARCEL BAYARD	1961	French P T.&T	397'7"	344 6"	51'3"	30'2"	21'6"	80,000**	4,800	4 418	Diesel-Electric	14.5	.78
LONG LINES	1962*	A T.&T	511'6"	447 6"	69'6"	37'6"	26'6"	140,000**	11,200	9,000	Turbo-Electric	15	.71

*Expected Delivery
**Approximate

closely related to an economical speed, it has an important effect on the motion of the ship in a seaway, not to mention its effect on cost or on the ability to contain the desired volume. The length must be sufficient for good seakeeping characteristics and directional stability and yet not too great to allow a turning radius small enough for adequate maneuverability. Longitudinal stability (i.e., resistance to pitching), so important to cable ships, is a function of the longitudinal moment of inertia of the waterplane area of the ship and therefore increases with the length cubed.

For good seakeeping ability there must be adequate freeboard forward, sufficient flare of the bow to keep the forecastle dry (in addition to providing adequate working space forward) and enough fineness of hull forward to cut through the waves. Thus, new cable ships, conforming to recent trends in naval architecture are generally of greater length and speed and are designed with finer hulls. Compare LORD KELVIN's bow with RETRIEVER's bow, shown in Figures 3 and 4.

The streamlining results in some sacrifice in cable stowage capacity since large cable tanks cannot be located as near the extremities, forward or aft. An example of this is apparent from a comparison of the location and size of cable tanks in the new RETRIEVER with those in the LORD KELVIN. Although the latter is a smaller ship of much earlier vintage, she has better than 50 percent more cable capacity. Also, it is interesting to note that the center of both LORD KELVIN's and CYRUS FIELD's No. 1 cable tank is located at a point 0.22 times the ship's length, L, from the forward perpendicular (which is a vertical reference line dropped from the intersection of the water line with the stem of the ship). However, the center of RETRIEVER's No. 1 cable tank is located at 0.38L and the ALERT, commissioned in 1961 by the British Post Office, has the tank located at 0.29L. Also, the diameter of LORD KELVIN's largest cable tank is 0.88 times the ship's beam (greatest breadth) or 0.88B, CYRUS FIELD's is 0.79B while RETRIEVER's is 0.58B and ALERT's is 0.86B. Note that ALERT is the only cable layer of the four ships and therefore is expected to have large tanks, whereas the new RETRIEVER reflects a definite reduction in cable tank size for cable repair ships. This

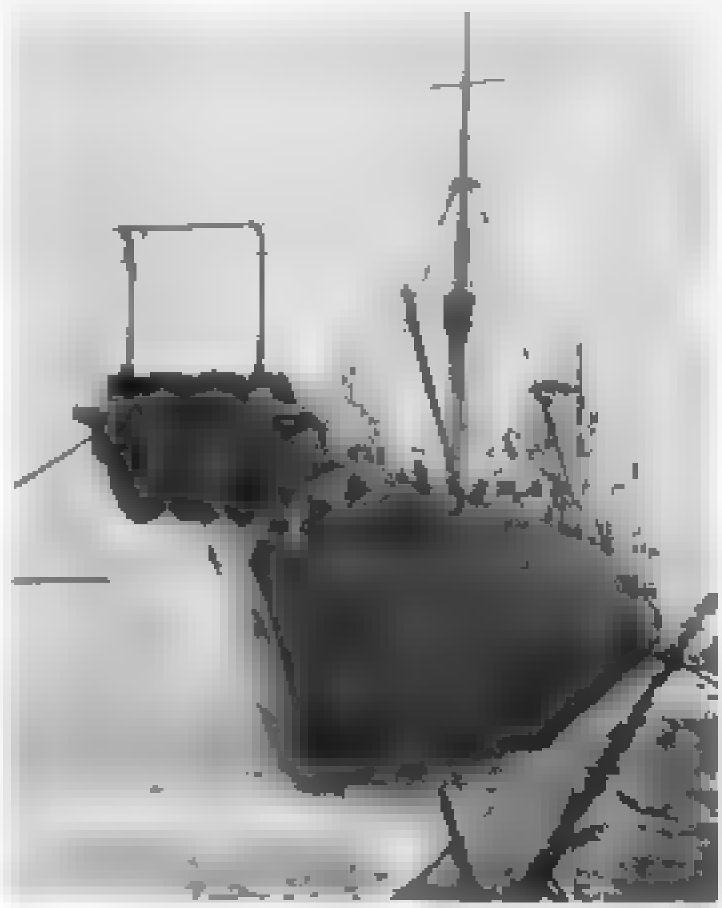
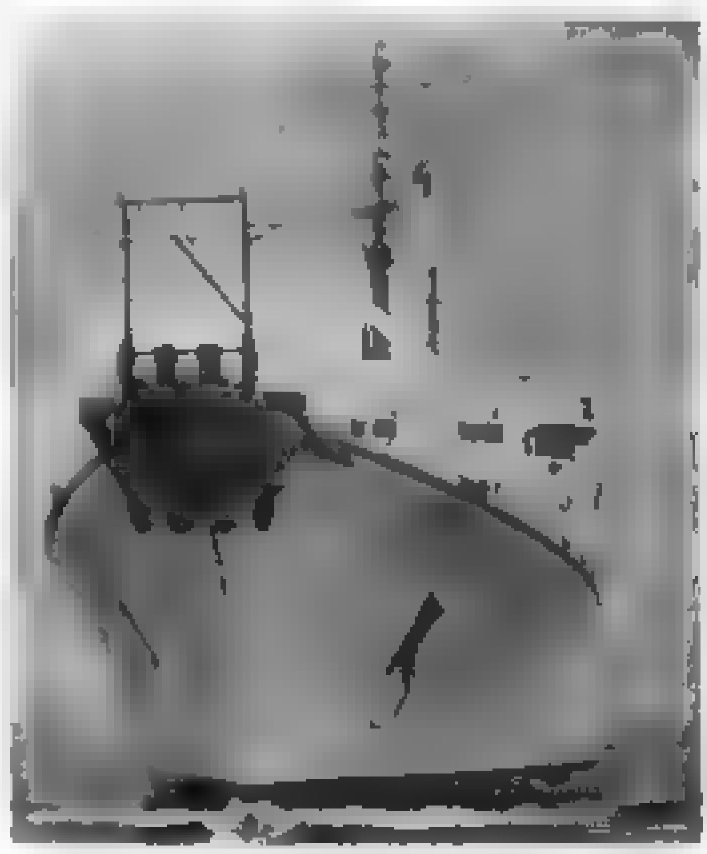


Figure 3. C.S. LORD KELVIN



(Courtesy of Cable & Wireless, Ltd.)

Figure 4. C.S. RETRIEVER. Notice flare forward, recessed anchor stowage, and proper placement of rubbing strips.

trend is also reflected in SALERNUM, the Italian ship which was built in 1955.

One explanation for the smaller tank capacities is the fact that non-armored cable which has been gaining widespread acceptance requires so much less space. Also, additional space can better be used for larger, more powerful propulsion machinery

A discussion of cable ship hull forms must mention the acceptance of the flush-deck type over the well-deck; compare Figures 1 and 2. Practically all new cable ship construction rejects the traditional well-deck.

Main Propulsion Machinery

Maneuverability, an essential characteristic of a cable ship, is a strong argument for twin-screw propulsion, and this has been the traditional choice whenever a choice has been allowed. Anyone who has seen and heard the constant flow of engine orders, "Half ahead Port," "Slow astern Starboard," "Slow ahead Port," "Stop Starboard," when the ship attempts to maintain a constant heading and position while standing up to a final splice with half a gale of wind blowing, will appreciate how hard it is for a single-screw ship to maintain proper station under similar conditions of wind and sea. The use of auxiliary devices such as a Pleuger rudder or other athwartships propulsive means, (to be discussed later) has not given the single-screw ship the reliable maneuverability of her twin-screw sister. Since reliability is by no means a minor consideration, this has resulted in the perpetuation of twin-screw propulsion as the standard

In the selection of the type of power plant there has not been complete agreement. However, lately there has been an increasing tendency to adopt the diesel engine as the prime mover. The change from reciprocating steam engines to diesels represents perhaps the biggest single modification in recent cable ships and the reasons for the change in many cases are indeed convincing. Based on a study made several years ago on a twin-screw plant of 2200 shaft horsepower per shaft, we find the following advantages in the diesel type over the steam type

a) Weight saving of approximately 100 tons for a diesel-electric plant and approximately 200 tons for a geared diesel plant with controllable-pitch propellers,

b) Fuel savings of over $20,000 per year based on a fuel rate for modern diesels of 0.37 lbs. per BHP-hour; this is about one-third that of modern reciprocating steam engines while the cost for diesel oil is not more than twice that of Bunker "C" oil,

c) Only one-third the weight of fuel need be carried to give the same cruising radius,

d) The fact that diesel oil need not be heated for pumping means that it can be stowed in double bottoms and wing tanks without radiation loss or excessive heat being transferred to the adjacent areas of the ship or to the sea,

e) Smaller space required for machinery, if diesels with controllable-pitch propellers are used. Diesel-electric plants may require as much space as steam plants,

f) Reduction in engine-room staff

Once the decision is made to use diesel engines the question then reduces itself to whether diesel-electric or geared diesels with controllable-pitch propellers should be used. A diesel engine directly connected to a fixed-pitch propeller is not satisfactory for a cable ship whether reduction gearing is used or not. Reduction gearing merely combines the benefits of both an efficient high-speed, lightweight diesel and a large, efficient, low-speed propeller, but the diesel engine, unlike the reciprocating steam engine, is essentially a constant-torque device the horsepower of which is directly related to engine speed. It is not stable at speeds less than about 30 percent of rated speed. Furthermore, even at speeds just above 30 percent the engine will soon collect carbon deposits. Since cable ships grapple for cables at the lowest possible speed at which they can maintain steerageway and often do so for hours or even days at a time, some form of

speed reduction between the engines and propellers is essential. The most favored forms are either diesel-electric propulsion or geared diesels with controllable-pitch propellers.

In the diesel-electric plant the diesel engine drives a generator which, through suitable controls, drives a motor mounted on each propeller shaft. This arrangement provides for good flexibility in addition to maneuverability throughout the entire speed range. Diesel-generators can be started and secured to meet the load requirements and can be used either in an isolated plant arrangement where a particular generator drives a particular propulsion motor or in a combined plant procedure where any single generator or combination of generators can drive either or both propulsion motors. The ALERT, MARCEL BAYARD and RETRIEVER are diesel-electric ships.

In the geared-diesel arrangement the diesel is essentially a constant speed, unidirectional engine; although some may have a partially-variable speed. Power is absorbed by a propeller, the pitch of whose blades can be precisely controlled from full-ahead through stop to full-astern positions in a matter of seconds by means of remote control stations which can be located anywhere on the ship. This type of plant eliminates the need for main propulsion generators and motors which are costly. In addition, the diesel-electric plant requires considerable space, and results in electrical losses of about 15 percent. On the other hand, the controllable-pitch propeller has not yet been accepted by cable ship operators because of a fear that it may not be sufficiently robust and reliable for cable ship service. This, despite the more than twenty years of proven reliability in icebreaker service in Norway and Sweden.

An interesting alternate solution is the one installed in SALERNUM. The ship is ordinarily diesel-driven enroute to and from the cable grounds but becomes diesel-electric while on the cable grounds or maneuvering in-and-out of port. This is accomplished by means of a coupling which connects the propeller shaft to the diesel only when on passage, during which time the main motors and generators are not energized but rotate freely, subject only to minor windage losses.

Although the general trend is toward some form of diesel propulsion, AT&T's new cable-layer, slated for service in 1962, will utilize steam turbines as prime movers. Here again, as in the diesel type, some intermediary device must be used for maneuverability and the obvious choice was electric drive. Turbo-electric propulsion is reliable, well-proven and has been widely used in many types of vessels from tankers to nuclear submarines in what may be called the intermediate power range. In high-powered ships like ocean liners where fuel economy is more important geared-turbines usually are preferred. In low-powered vessels like cable repair ships the benefits of the steam turbine are minimal, although there are available more qualified steamship engineers than diesel engineers. When a ship is to be stationed at a remote port, this still may be the decisive factor. The almost complete freedom from vibration is another attractive feature of the turbo-electric drive.

Auxiliary Propulsion

As already pointed out, maneuverability is an essential characteristic of a cable ship, particularly a cable repair ship, which often is required to maintain for hours a constant heading against wind and sea. Moreover, the necessary heading is not necessarily the optimum one with respect to wind and sea. Under such circumstances the ship attempts to augment the effect of the rudder by rapid changes in speed and direction of the propellers. The rudder, being a fluid-flow device, has very little effect on directional stability when the ship is making little or no headway. This is particularly true in a twin-screw, single-rudder ship where the rudder does not lie in the wake of either propeller.

Obviously there is a need for some kind of device at the bow which can exert an athwartships force, either to port or starboard, independent of ship speed, in a manner similar to that of a tugboat nestling under the bow of an ocean liner. In

recent years a number of different types of devices which can exert such an athwartship force have been utilized in many types of ships. It must be noted that the magnitude of such a force need not approximate that of a docking tug simply because it takes time for a tug to jockey into the proper position to exert its force; whereas the effect of an athwartships populsion device can be varied quickly as required and is available immediately. Thus, many skippers under moderate conditions would rather have a reliable 200-500 HP athwartships propulsion device to draw upon than a 1500 HP tug.

The Pleuger rudder consists of a submerged motor-driven propeller integrated as a unit with the ship's rudder. Theoretically it is the ideal solution to the rudder's basic ineffectiveness at low speed. Furthermore, in event of a breakdown of the ship's main propulsion system, the Pleuger rudder may develop enough power for the ship to limp home to port. In addition, the rudder motor may easily be used for the ship's propulsion while the ship is grappling at 1-2 knots. At the time of conversion to a cable ship, the ill-fated OCEAN LAYER was fitted with a Pleuger rudder in order to compensate for the lack of maneuverability in this single-screw ship. The equipment worked fairly well, but there were a few maintenance problems. Other cable ships with Pleuger rudders include NORDENHAM, IRMGARD PLEUGER and MARCEL BAYARD.

Most athwartships propulsion devices are installed in the bow in some form of tunnel which runs from port to starboard. There is a wide variety of types now available. Perhaps the simplest is a small propeller driven from a shaft which runs through a seal into the ship where it is driven by a reversible motor as shown in Figure 5a. There are many variations in the layout of the motor and the shafting, some using vertically mounted motors with bevel gears but the equipment is all fairly simple.

Some of the more intricate bow thrusters include the KaMeWa controllable pitch unit as illustrated in Figure 5b. This equipment has the advantage of being able to develop a wide range of thrusts from zero to maximum in either direction and is powered by a constant-speed prime-mover, either diesel or electric motor. A single lever, which can be located anywhere in the ship provides infinite and immediate control over the pitch of the blades which are positioned by a hydraulic system within the hub.

Another device with this same capability, the Voith-Schneider cycloidal propeller, consists of a rotating horizontal round plate, at the periphery of which are mounted a number of spade-like vertical blades. As the plate rotates, the pitch of the blades is constantly being changed in such a manner as to exert thrust at a specific point on the periphery. As each blade passes this controlled point its pitch is adjusted so as to produce thrust in the desired direction. This equipment, which is in wide use in many types of ships and which is installed in the ALERT and RETRIEVER is illustrated in Figure 5c.

Cable Machinery

The reciprocating steam-engine-driven cable machinery which has long been the standard workhorse has now given way to electric drive. The steam engine was superbly suited for the job because it was rugged, reliable, simple and capable of developing fairly high torques at zero speed and in addition, high speed at low torque. Furthermore, when picking up cable in a moderate sea with the ship's bow pitching up and down, it was possible to set the steam throttle valve so that when the bow was on the crest of a wave and the cable tension was at a maximum the engine would slow down or even stop. Then when the ship's head fell into the trough of a wave and cable tension would drop rapidly, the engine would run faster to pick up cable at minimum tension.

To duplicate these capabilities in an electric drive it was necessary to use either a hydraulic variable-speed unit (as in RETRIEVER and MARCEL BAYARD) or a direct-drive electric motor as part of a constant-current series circuit involving other auxiliary machinery, (as in ALERT MONARCH, and SALERNUM).

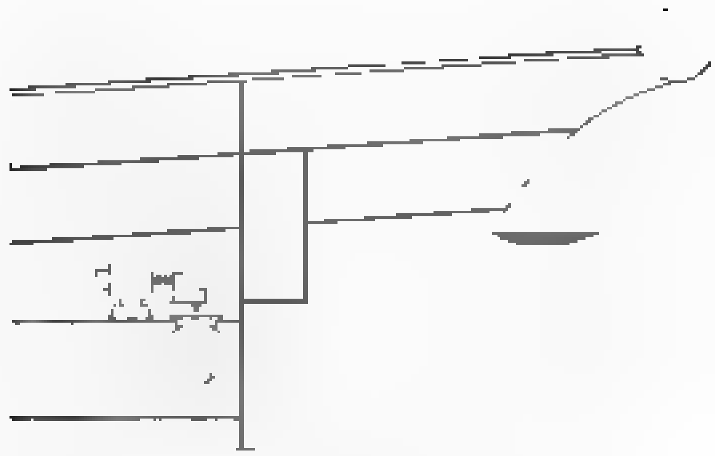
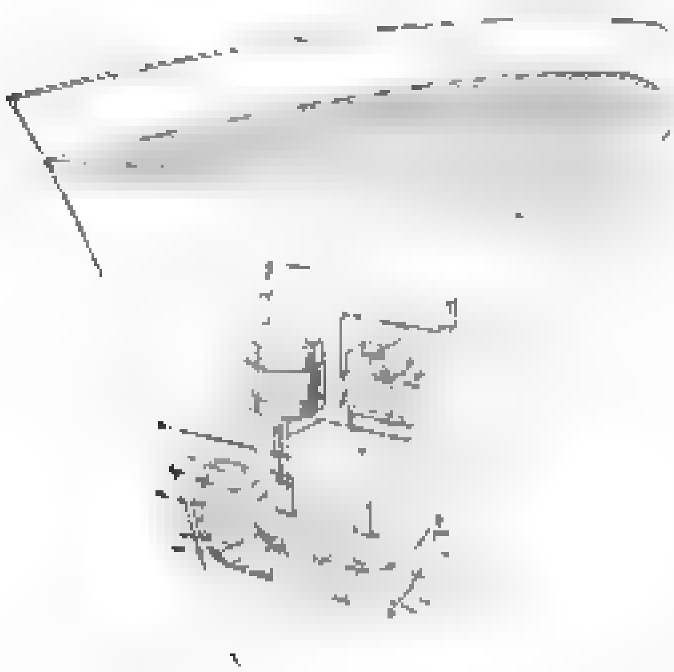


Figure 5a. Screw-Propeller Bow Thruster



Courtesy of Bird Johnson Co. N. Y.

Figure 5b. KaMeWa Controllable-Pitch Bow Thruster

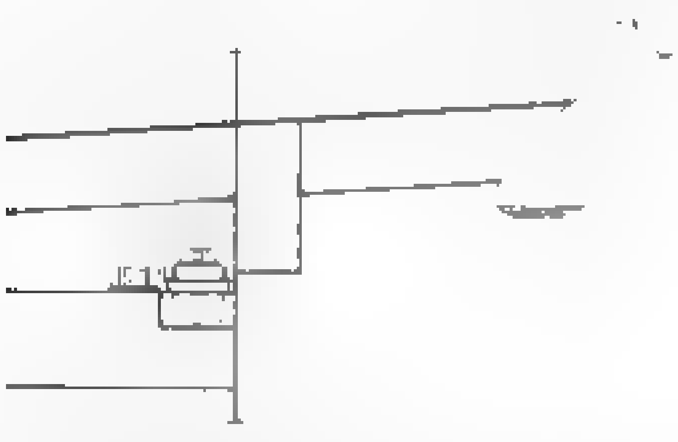


Figure 5c. Voith-Schneider Cycloidal Bow Thruster

In the electro-hydraulic unit a constant speed electric motor drives a variable-stroke hydraulic pump, the positive displacement of which is dependent upon the positioning of a central tilt box which varies the travel of a number of pistons acting within their own separate cylinders. The flow of oil is then varied to drive a fixed-stroke hydraulic motor which drives the cable drum shaft.

In the constant-current system, which is 300-amperes in MONARCH and 800-amperes in ALERT, a generator, or series of generators can be used to drive a number of motors in the constant-current ring. The torque developed by each motor is controlled by varying its field excitation current. If the load falls below the adjusted torque, the motor rotates in the picking-up direction until the load again increases to the pre-set stalling torque. If the load increases, the converse occurs.

The constant-current system has the same power/torque characteristics as the steam engine but does not have the latter's disadvantages such as radiation losses in long steam lines and the water-drainage problem after long periods in the stalled condition. Another advantage of the constant-current system over the steam engine is the re-generative-braking capability of the former. On long payouts, the machine is "driven" by the cable as it is being paid-out, and therefore can supply power for other electrical equipment.

Navigational Aids

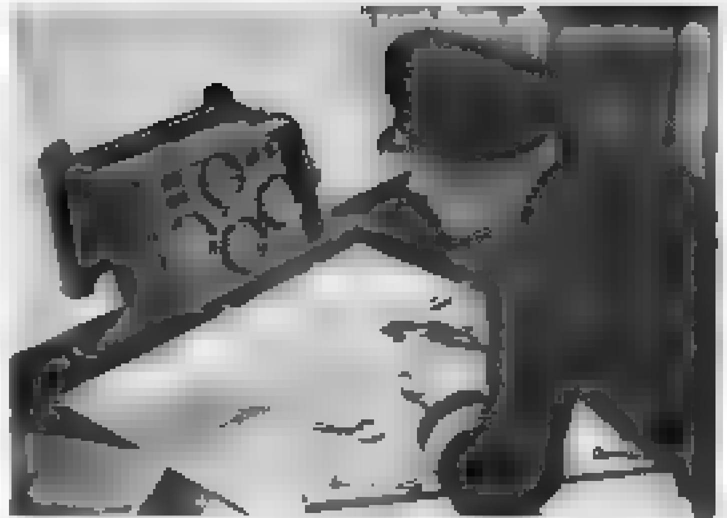
As new navigational devices have become available they have been quickly pressed into service in cable ships where the need for precise navigation is paramount. Some recent developments, in both navigational and fault localization aids, have been reported in previous issues of the TECHNICAL REVIEW[1,2] but perhaps a brief review of additional developments may be in order.

True-Motion Radar has now been installed in many cable ships, both old and new. The ability to determine instantly the true course of a radar target without plotting is the most important feature of True-Motion Radar. A True-Motion radar display is achieved by cranking in the ship's own speed and course information which is then utilized to alter the position of the electrical center of the display about which the range traces rotate. Thus,

the ship moves towards fixed objects on the screen instead of vice-versa and a true bird's-eye view is obtained. Stationary objects such as land masses and buoys are immediately distinguishable from moving objects since they have no after-glow tail. Furthermore, the after-glow tail on moving objects, the brightness of which is a function of the persistence of the picture tube, clearly shows true direction rather than apparent direction and therefore does not require the use of vector analysis to determine the other ship's true course and speed.

Another new device, the Decca Navigator, pictured in Figure 6, has been generally accepted by cable ships operating in any of the several Decca chains throughout the world. A Decca chain consists of a master station plus three slave stations which are identified as Red, Green or Purple slaves. The master and one slave constitute a pair which will give a line of position. The stations transmit low-frequency unmodulated continuous-wave signals. The signals for a pair of stations, master and one slave, are so related in frequency that a common frequency may be derived from each by means of multiplying circuits in the receiver. The use of different but compatible frequencies eliminates interference problems. The phase relationship of the derived common frequency of the pair of stations determines the geographical location. When the signals of two stations are in phase, the phase-measuring instrument on the receiver indicates zero phase difference which means the ship must be located somewhere along one of the constant-phase-difference lines which radiate hyperbolically with respect to the two stations. The same procedure is followed with the master and another slave station to obtain another line of position which, together with the first, establishes a fix.

The Decca Navigator system although of shorter range, is much more accurate than Loran or celestial navigation and is considerably less cumbersome in obtaining fixes. Decca, once set up is a continuous-reading device which requires no further adjustment. This is an important



(Courtesy of Decca Radar Inc., N. Y.)

Figure 6. Decca Navigator

feature on any ship where the deck officers are as busy as they are on a cable ship.

Another system using continuous-wave transmitters and phase-comparison techniques is the Raydist Range System. This system has a very short range, but is more accurate than hyperbolic systems where the angles of crossing become more acute as the ship moves away from the stations. The accuracy is such that it can be used successfully for ships' speed trials in lieu of land-based measured-mile markers as was done during the trials of S.S. UNITED STATES[3]. However, as yet this equipment has not been generally accepted by cable ship operators.

Systems similar to Raydist in accuracy and logistic mobility are derivatives of the Decca system, known as Lambda and Hi-Fix. Like Raydist, they avoid the limitations of hyperbolic patterns for high accuracy work but retain the valuable features of lane identification and greater range of the Decca system. Both systems have been used on board cable ships.

Habitability

In the last few decades living quarters aboard ship have improved considerably. This was due to a number of reasons: first, the elevation of shore-side standards in the principal maritime nations; second, the influence of seamen's unions; third, the passage of such ameliorating legislation as the Jones Act[4]. This law raised the level of the seamen and extended the ship-owner's liability. For example, it has been held that the failure to properly notify the

ship's cook of an impending storm renders the ship unseaworthy[5], or, employing a seaman with "a propensity to evil conduct" also renders a ship unseaworthy[6]

The objective today, in new construction, includes such things as individual cabins, wash basins, mirrors, desks, air-conditioning, crew recreation rooms, libraries, and even portable swimming pools as provided in the new RETRIEVER. All officers have individual cabins and their own bathrooms. The Master and department heads usually have three-room suites consisting of dayroom, bedroom and bath, all lavishly furnished in natural woods or high-gloss fire-proof composition panels. Overheads consist of smooth-finished panels with recessed lighting.

While the above is becoming the present-day standard in the industry, it is difficult to meet these requirements in a cable ship because of the relatively large crew for its size.

The increased "hotel-load," which inevitably requires more space, is being accommodated by building ships larger, more efficient utilization of space, and greater attention to this feature at the earlier stages of design.

Conclusion

No discussion of cable ships would be complete without mentioning the leviathin GREAT EASTERN[7] even though she was not built originally as a cable ship. The GREAT EASTERN 693 feet long, 120 feet wide, with six masts and five funnels, 58-foot paddle wheels and a 24-foot screw-propeller was the largest ship ever used as a cable ship. In fact, when she was launched in 1858 she was the largest ship ever built and held this record until 1906 when the ill-fated LUSITANIA was launched. Even AT&T's 512-foot cable ship appears small in comparison to the GREAT EASTERN. But sheer size does not make a cable ship.

The sophistication and novelty of some of the new devices and equipment now in use on cable ships is even more remarkable when we consider that naval architecture is by nature a conservative science and seamen as a general rule are reluctant to try new machinery in preference to the old well-proven forerunners. Because of this inertia the recent innovations are remarkable indeed

Acknowledgment

The author wishes to acknowledge with thanks the cooperation and advice given by MR. C S. LAWTON, General Operations Manager, International Communications

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MR. R. P ROMANELLI assists in the operation and maintenance of cable ships and plant. In addition, his duties include the design and manufacture of ocean cable and the study of trawler damage to cables. Mr Romanelli received a Bachelor of Science degree from the U S. Merchant Marine Academy in 1950. After a tour of duty at sea as a Third Assistant Engineer he was employed by a firm of naval architects. He then served three years in the Navy where he was stationed aboard an aircraft carrier and ashore in Hull Design duties. Upon release from the Navy in 1956 he joined Western Union where his first task was to prepare plans and specifications for a replacement for C S. LORD KELVIN. Mr. Romanelli is an Associate Member of The Society of Naval Architects and Marine Engineers and holds the rank of Lieutenant Commander in the Naval Reserve.

H. P. KRANTZ, Senior Project Engineer

U.S.A.F. Technical Control—Part II

A Completely Modern Traffic Control Center

In Part I of this article,* the general plan of these modernized centers was outlined as being the most up-to-date facility for the rapid, accurate handling of communication channel routing. Security requirements were discussed and equipments in the RED or clear text area were described. Part II describes traffic handling in the BLACK or encrypted text area, the facility for monitoring of channels in both RED and BLACK areas, and centralized maintenance.

Encrypted Area

THE EQUIPMENT provided for communications channel routing after encryption is shown in the block diagram in Figure 1. The TERMINAL EQUIPMENT is not part of the new Technical Control facilities. As in the RED area, the normally expected jack field is provided for channel patching in an equipment patching facility. After conversion to audio frequencies in the terminal apparatus, an audio patching facility provides means for manually routing terminal apparatus to available line facilities.

Equipment for checking audio channel quality is available on an adjacent TEST BAY. The terminal apparatus is replaced by a LINE ISOLATION relay for a circuit assigned to local land line facilities. Two blocks represent the telephone ringdown and on-line monitoring facilities. The BLACK AREA SWITCHING cabinet, with leads into the RED area house the control and monitoring probes used by the quality control console operator. Receiving cut relays, discussed in Part I are housed in the RELAY SWITCHING BAY

It should be noted again that in this BLACK area a separate station battery for 60-volt polar supply is provided in addition to a separate ground return bus. This supply is identical to that in the RED area except in total capacity. This two-station battery system insures maximum security between the clear and encrypted areas.

The EQUIPMENT PATCH BAY provides the jacks necessary for reassignment of encryption or battery isolation devices to operating or fallback terminating equipment. The jack arrangement is a simple tip-tip-normal through connection of two vertically adjacent jacks. Sending jacks are located directly above receiving jacks of the same circuit. One hundred circuits are provided on each assembly with an additional twenty special purpose tip and sleeve circuit combinations. Auxiliary jacks for trunking, test transmitter patching, and circuit terminations are also provided. Each facility is equipped with an intercom station, as illustrated in Part I of this article.

Audio Patching and Test Facility

The terminal apparatus may be one of a variety of types, according to the purpose. It provides the means for combining and/or converting telegraph signals into audio frequency channels for transmission over any number of available mediums. The Audio Patch Bay is the last point in the circuit where channel and technical control operators have access to the routing of a particular group of circuits. These relatively simple jack circuits in the Audio Patch Bay are shown in Figure 2. The associated Audio Testing Bay shown in Figure 1, is an assembly of highly accurate apparatus for measuring audio channel quality. It consists of the following appearances, terminated in jacks for convenient use with channels, connected to the interbay trunks shown in Figure 2:

(a) Twelve Standard Tone Generator outputs with a frequency of 1000 cps $\pm 1\%$ at a level of 0 dbm $\pm .1$ db and an impedance of 600 ohms $\pm 1\%$. Plugging into

* Part I—published in Western Union Technical Review, Vol. 16, No. 1, January 1962

one output will not cause the other outputs to vary by more than 1 db. The combined noise, hum and distortion level at the individual outputs is less than −50 dbm. All

(c) One Distortion and Noise Measuring Set, General Radio Type 1932-A.

(d) One audio vacuum tube voltmeter calibrated as a V.U. meter

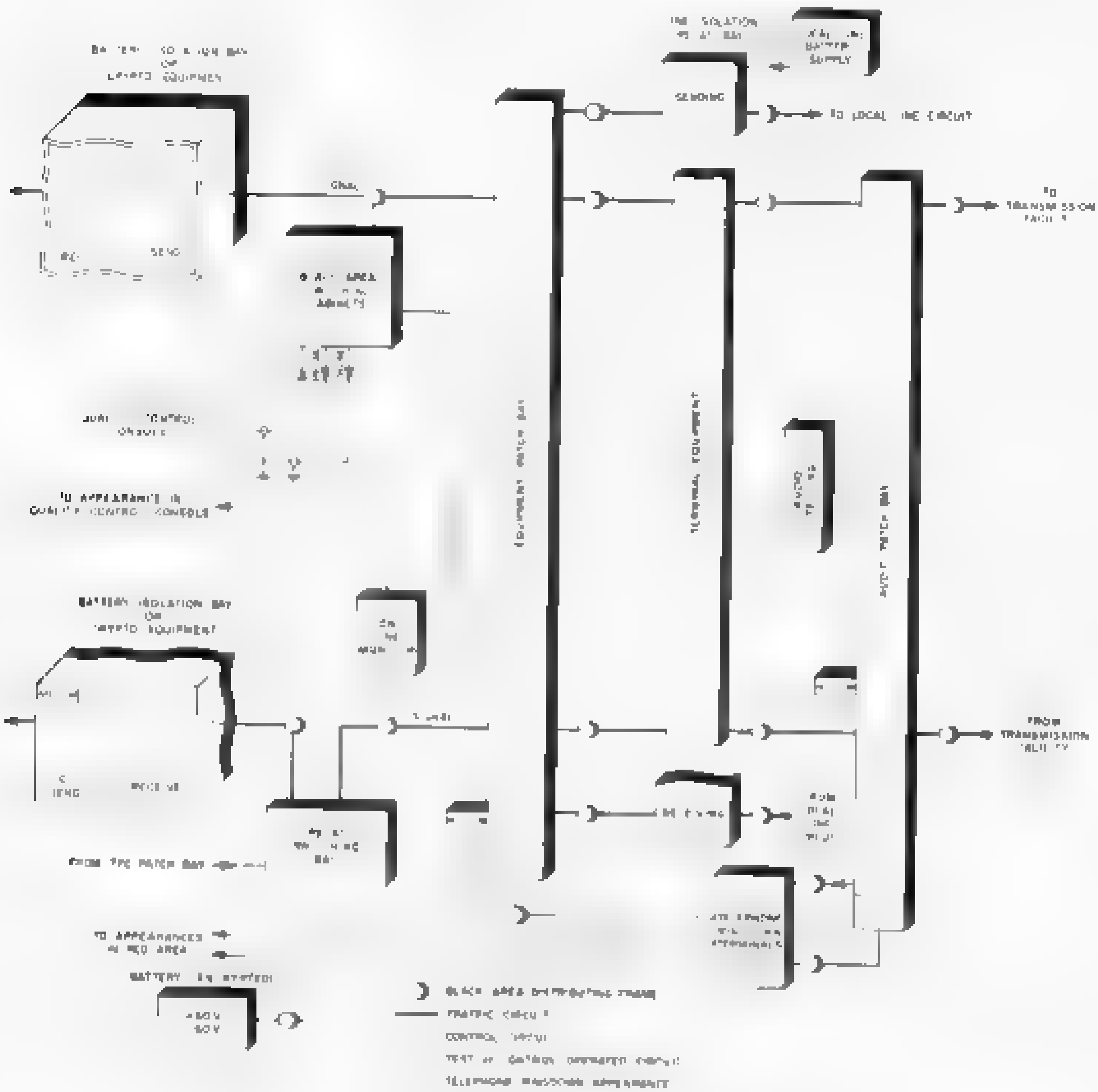


Figure 1. Block Diagram — Encrypted (Black) Area

controls of the generator are by screwdriver adjustment to prevent accidental maladjustment.

(b) Six Audio Signal Generator outputs, each of which may be varied from 50 to 15K cps, and each of which has an impedance of 600 ohms ±1%. The level of each output may be continuously varied, from +20 to −70 dbm. The combined noise, hum, and distortion level at the individual outputs is less than −50 dbm.

(e) Twelve Line Terminations with an impedance of 600 ohms ±1% and a maximum power handling capability of +30 dbm.

(f) Two Audio Mixing Pads providing a balanced resistive network with an input and output impedance of 600 ohms capable of mixing two signals, each signal having a level of +20 dbm.

(g) Four Fixed Audio Attenuators providing a balanced resistive network and

having an attenuation of 10 db ± .1 db and input and output impedances of 600 ohms for an input level capability of at least than +20 dbm.

(h) Four Variable Audio Attenuators providing a balanced resistive network with a minimum attenuation of zero, and an indicated increase to 100 db (in one db steps). Input and output impedances are 600 ohms with an input level capability of at least +20 dbm

(i) Two Isolation Transformers with a 1 1 ratio, accurate to 1% at 1000 cps. The response curve is flat within .5 db, over the range of 300 to 3000 cps, when the source and load impedances are 600 ohms resistive. Each transformer has a power handling capability of at least +20 dbm.

(j) Two Bridging Transformers having an impedance transformation ratio of 600 to 20,000 ohms and accurate to 1% at 100

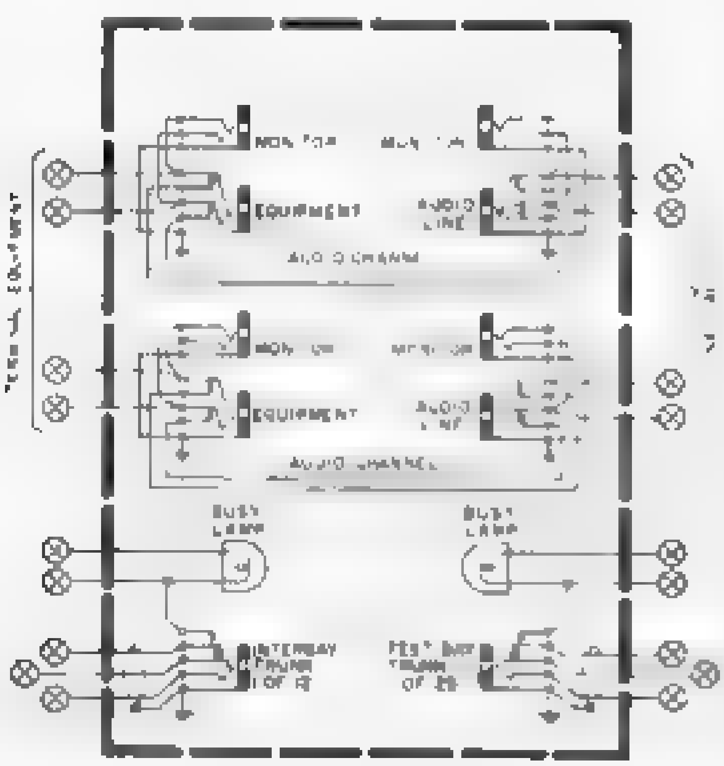


Figure 2. Audio Patch Bay

cps. The response curve is identical with that of the Isolation Transformer listed above.

(k) Two Line Amplifiers, on a dual-channel panel having a response curve which is flat (within .5 db) over the range 50 to 15K cps and a maximum gain of 30 db, variable by screwdriver adjustment. The output capability of each amplifier is +10 dbm. The input and output circuits are balanced, and match 600 ohm source and load impedances. The combined noise, hum, and distortion level, introduced by the amplifier is less than —60 dbm

(l) One Monitor Amplifier with a balanced input of 20,000 ohms, capable of delivering two watts across a matched load when bridged across a 600-ohm balanced line, which is carrying a 1000 cycle signal at a level of —10 dbm. The distortion, introduced by the amplifier when it is delivering two watts at 100 cps, is less than 3%

Line Isolation Facility

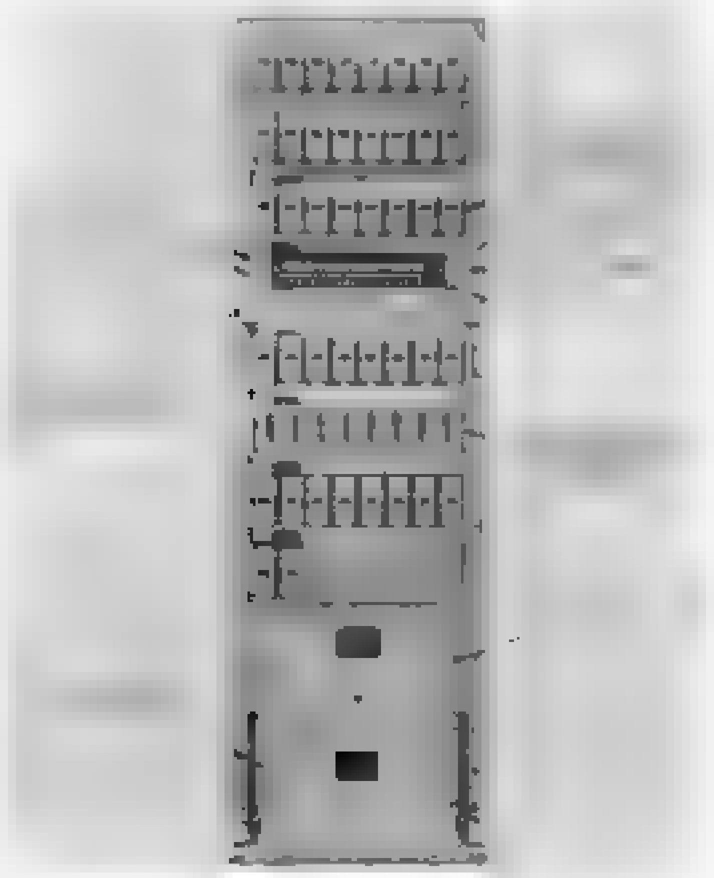
The Line Isolation Facility is provided to convert instation 60-volt polar, 20 milliampere signals to the required line-operating characteristics. This replaces terminating equipment for all circuits going directly to local land lines. These are primarily polar conversion relay circuits with various capabilities on the line side depending upon whether the local circuits are neutral or polar. These variations are made by strapping at the rear of each panel which mounts three duplex circuits. In connection with these relays is a separately mounted power supply to provide the line voltage. In the station at Fuchu, this is a 120-volt polar supply. At Croughton, where all of the station battery in the BLACK area is determined and provided by local regulation, 80-volt polar battery is provided. A jack field is provided on each assembly to permit routing of the forty-eight instation circuits to various line facilities. A large meter for monitoring purposes is terminated in the jack field. Additional racks may be added to accommodate the number of channels assigned to local circuits

Telephone Ringdown Facility

Coordination of encrypted and audio circuit changes is accomplished mostly via the voice order wire provided by the Telephone Ringdown Rack, shown in Figure 3 Fifty circuits are provided for connection to four appearance locations. These appearances consist of a handset and five

illuminated push buttons for line selection. The schematic of the TELEPHONE RINGDOWN circuit, is shown in Figure 4.

Operation of the desired line-button connects the operator's handset to the ringdown terminal and line. A steady, busy light appears at all parallel locations. The called station receives a flashing light in the center of its selected push button, at all appearances. When the call is answered by depressing the button at one of the appearances, the busy light lights up, indicating to all others that the call has been answered. A push to talk button, in



(Courtesy Automatic Electric)

Figure 5. Telephone Ringdown Rack

the handset, is connected through the jack circuit to open the transmitter circuit while listening. This button may also be connected through the system to an ultimate control which would shut off interfering transmission carrier on a bi-directional, single-frequency carrier

Quality Control Facility

Signal monitoring and testing are features which require constant attention. The operators are expected to maintain a working system, and to know how and when to reroute equipment circuits which are in trouble. When traffic is moving constantly over hundreds of channels, this capability of the operators can be aided by equipment designed to eliminate fatigue and to provide quick, clearly defined measurements of signal quality. For this purpose a Quality Control Facility is provided

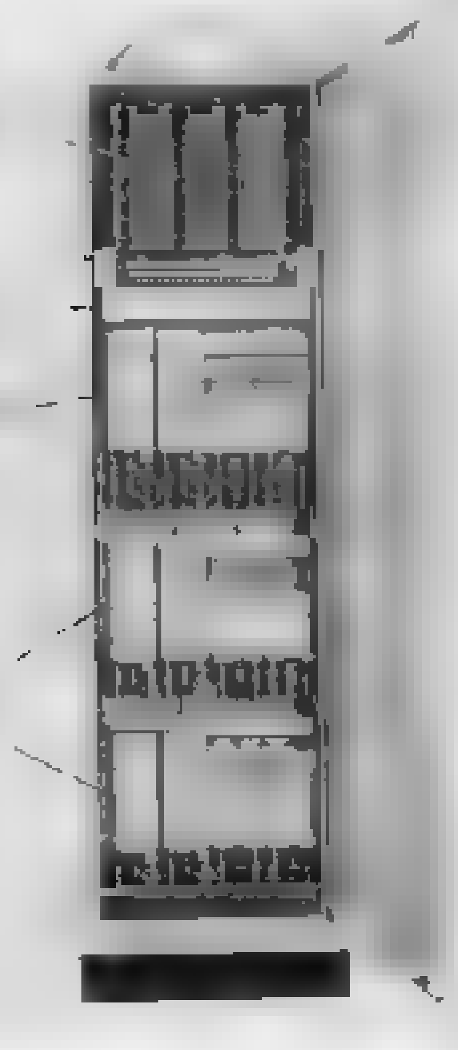
This facility includes consoles with controls conveniently located to a seated operator, and where appearances from an electronic on-line monitor facility are concentrated. The switching systems which provide access to both the RED and BLACK sides of a circuit from the console, are also considered a part of the facility

Figure 4. Telephone Ringdown Circuit

Figure 5 shows the Switching Cabinet for the RED area. Identical equipment, except for the number of switched leads, is provided in the BLACK area. These two cabinets are located adjacent to their respective cross-connecting frames so that the leads to a circuit are less subject to interferences or loss of security. From the Switching Cabinet to the Quality Control Console, the connection to these leads are shielded and the through circuit protected by a high impedance. Both switching systems, RED and BLACK, operate simultaneously from dial-actuated pulses Three-digit circuit numbers are assigned so that the first digit represents the switchboard location and the second and third digit represent the jack position. Coupled with the logical assignment of jack posi-

tions, this association is quickly learned. Therefore, the console operators require little reference to a directory for the proper dial number. Based on well established two-motion switching techniques for the number of lines involved, this system allows rapid access to all channels. When a circuit has been previously accessed from a different console, a busy indication alerts the operator to that fact, and an interlock prevents his accidental insertion of a second set of test apparatus.

Figure 6 shows the Quality Control Console provided for the monitoring of traffic passing through the Technical Control Center. Three of these consoles are placed in a row to give maximum coverage with minimum operator fatigue. Each console is of such configuration that all controls, instruments and visual displays may be manipulated or seen by one seated operator. The writing surface and teleprinters are located at a height most efficient for keyboard operation. Winged



(Courtesy Automatic Electric Co.)

Figure 5. Switching Cabinet (Front View)

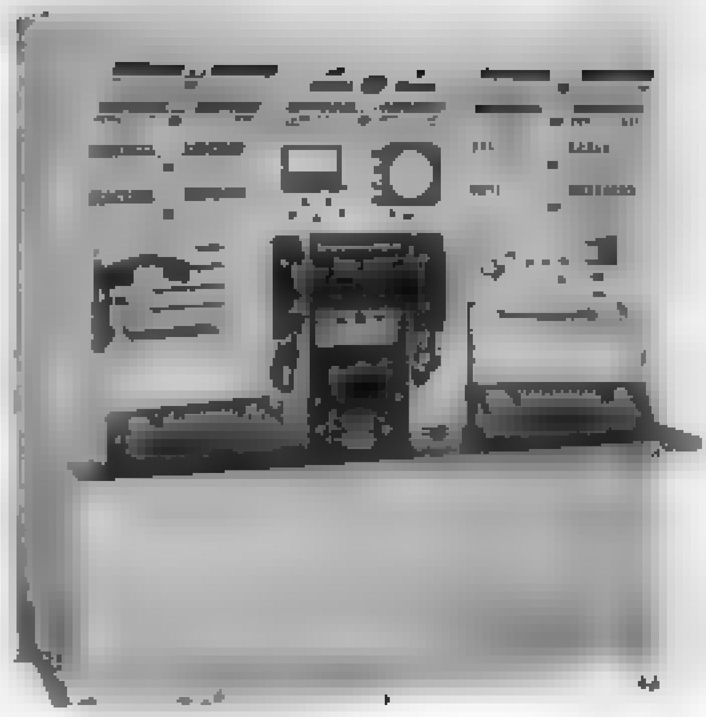


Figure 6. Quality Control Console

sides and sloped upper panels are extended so that the seated operator can reach all controls without stretching or rising from his chair. Each console includes the following appearances for facilities previously discussed.

a) An order-wire panel on the lower left wing. This includes a telephone handset with ten push buttons and teleprinter with twenty-five push buttons.

b) An intercom station on the left of the lower center panel. This has a handset and ten station selector push buttons.

The circuit elements for these facility appearances are located in the side compartments below the shelf. The middle compartment provides storage space for printer paper rolls, etc.

Monitor Teleprinter and Control Panel

The lower part of the right hand wing is the monitor teleprinter and control panel. This apparatus is shown in the block diagram of Figure 7. The panel is recessed in the console to prevent accidental operation, and to provide the following controls which actuate the functions required for operation of the console:

a) A pair of interlocked illuminated push buttons labelled DIAL and RELEASE. When depressed the DIAL button acti-

vates the dial control, lights "green," and turns on the traffic printer motor. The RELEASE button is lighted "red" when the switching system has found the desired circuit. It remains lighted until all testing functions have been completed. When the RELEASE button is depressed all lights "go out," the switches are released, and the entire switching system is deactivated.

b) A dial which controls the switching by any three digits and causes the automatic selection of operating rate for test equipments

c) An interlocked group of two rows of illuminated push buttons on a clearly colored background of red and black, depicting the security areas. These rows are labelled SENDING on the top row and RECEIVING on the bottom row Each row contains four buttons; two for each area and designated PRINTER and METER. When depressed, the button is illuminated and performs the function of placing its designated device in the chosen position in the circuit. When two of these buttons are depressed simultaneously, the operator

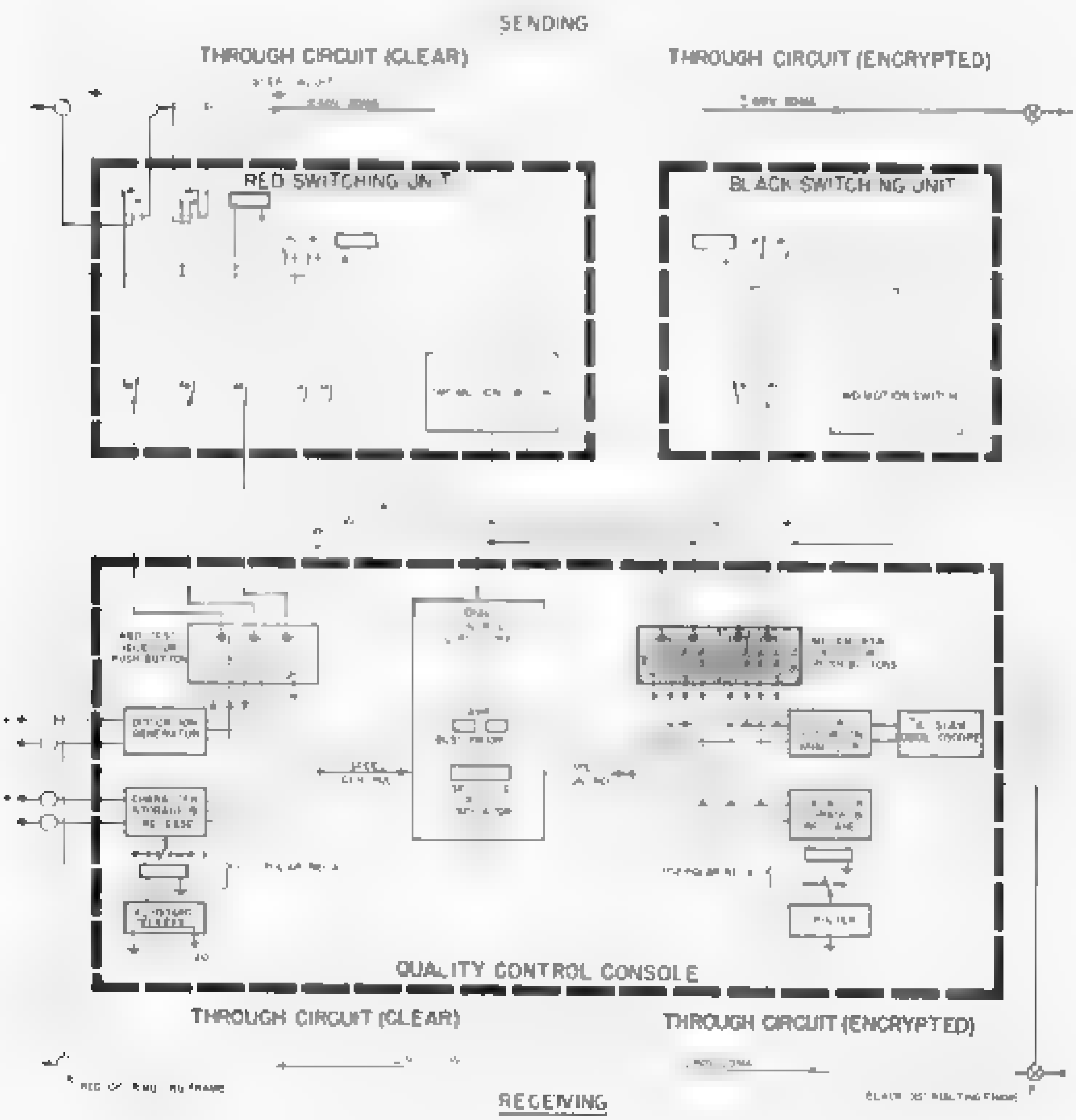


Figure 7 Block Diagram — Operating Console

can observe traffic on his Printer in the "clear" area and its distortion in the encrypted side on the meter display.

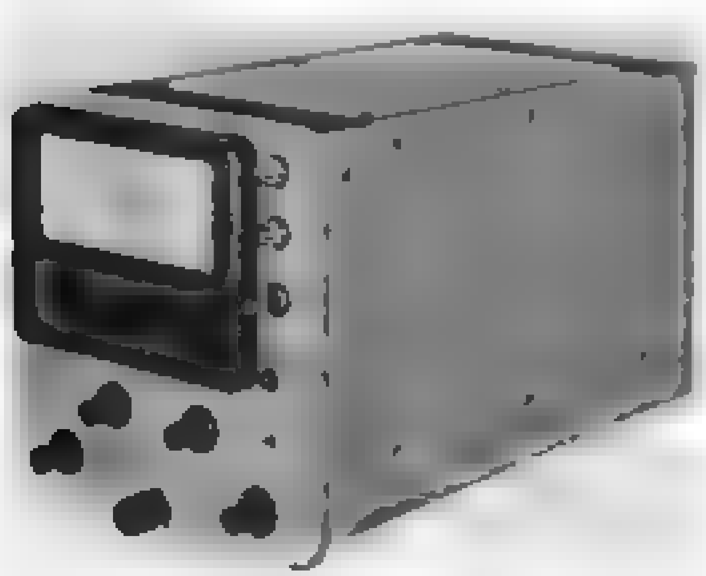
d) An interlocked group of three illuminated push buttons are designated SENDING CONTROL: CLEAR — KEYBOARD — PATTERN. The CLEAR button removes the console from access to the sending circuit for test message or teleprinter-talk purposes. It is lighted "green" when such conditions exist upon initially dialing or when depressed to unlock either one of its associated buttons. The KEYBOARD button, when depressed, is lighted "red" thus extinguishing the "green" light of the CLEAR button, and places the traffic printer keyboard (through a Character Storage and Release device) in the traffic circuit. Simultaneously, the signal path and step pulse path are transferred from the traffic circuit to the console. The PATTERN button when depressed is lighted red, and performs the same functions as the KEYBOARD substituting the Distortion Pattern Generator in the traffic circuit.

e) A pair of multi-position switches identified as BAUD RATE — SEND and BAUD RATE — RECEIVE which are provided with twelve positions. Each switch has a skirted knob appropriately labeled with red and black backgrounds to indicate the rate set. The positions labeled on each switch indicate the known combinations of nominal baud rates, the first eight of these may be automatically set. These are

RED	BLACK	
MAN	MAN	for circuit not normally assigned require manual operation
45	37	for encrypted traffic (60 word)
45	45	for battery isolation traffic (60 word
50	37	for encrypted traffic (66.6 word
50	50	for battery isolation traffic (66.6 word)
74	61	for encrypted traffic (100 word)
74	74	for battery isolation traffic (100 word)
—	150	for combination multiplex
37	37	for testing with pattern generator
61	61	for testing with pattern generator
150	150	for testing with pattern generator

f) A large square illuminated push button, labeled MANUAL BAUD CONTROL, becomes illuminated when depressed. This button disables the automatically set baud-rate-control-holding feature allowing the operator to choose any baud rate for the operation of his console equipment by turning either of the knobs in (e) to the desired setting.

g) The lower center panel contains the dial controlled rotary file and automatic rate-setting Findamatic unit. The drum of this unit is positioned in its rotation by lighting one of the 100 lamps in a fixed ring. When this light source is interrupted by a vane connected to the drum, it stops with the channel indicator appearing through the window in view of the operator. Since the original concept of Tech Control contemplated a maximum of four hundred channels, the drum is divided into four bands each band representing 100 channels. The desired band is identified in operation by a lamp over the appropriate section of the window. Behind this circuit identification a group of five set screws actuate individual leaf switches, which control the automatic operation of console equipment. In the center of this panel, at the operator's eye level, two lamps indicate busy or priority conditions when either exist.



(Courtesy Stelma Inc.)

Figure 8. Digital Distortion Analyzer

Signal Quality Measurements

The Digital Distortion Analyzer, shown in Figure 8, provides for operation at nominal rates of 37-, 45-, 50-, 61-, 74- and

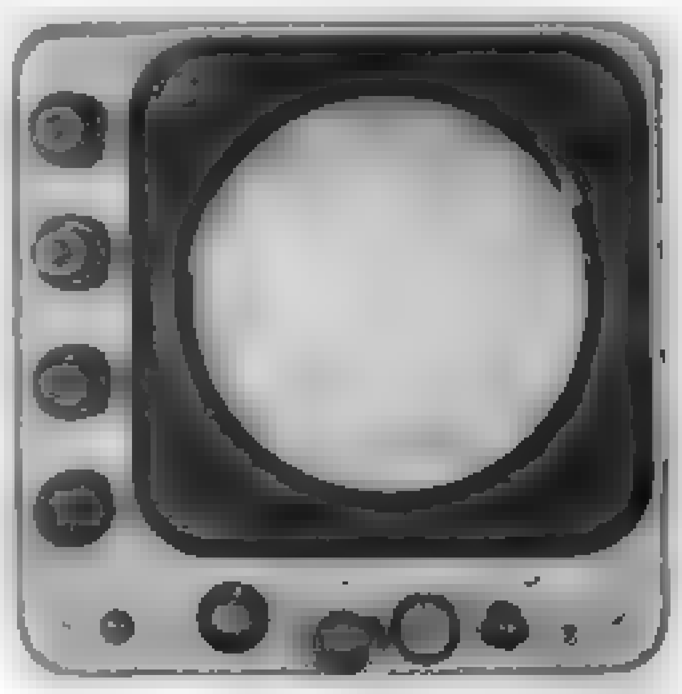
150-bauds with a 5- or 8-unit start-stop code. Automatic selection of operating rate is dependent upon a mechanism within the A-Scan Oscilloscope, whenever the rate switch in the Analyzer is in the AUTOMATIC position. A switch is provided to permit the operator to over-ride an automatic rate selection. A unit code selection switch provides selection of a 5-unit, 8-unit code or remote control, a 5-unit code is normal but may be adjusted automatically to accommodate an 8-unit code. An interlock is provided between the rate switch and the 5- or 8-unit code selection switch. All positions have provision for either code but strapping within the analyzer is such that the 8-unit code will be selected for only the 45- and 74-baud rates.

A transition select switch permits the operator to observe distortion on any signal element or on all signal elements within a character. A switch permits the operator to observe distortion either on an average or a peak basis. An additional push button, marked RESET, is used for resetting the circuitry to zero when observing peak distortion (a peak reading remains until manually reset to zero). Another switch permits the operator to observe separately, *mark-to-space* or *space-to-mark* transitions with respect to an initial mark-to-space transition. Two colors delineate the required control markings. The most prominent marking is used to indicate the control setting most likely to be "normal"; while the remaining settings are suppressed in tone. The display is a five inch meter, with an accuracy of 1%. Distortion is calibrated in percent from 0 to 50. Mark-to-space or space-to-mark (direction of the distortion sense) is indicated by illuminated lamps to the right of the meter.

The A-Scan Oscilloscope, shown in Figure 9, has a long-persistence screen with a graduated scale corresponding to the 5- and 8-unit code. The face of the scope is etched to permit using it as a current-measuring instrument with an accuracy of 5%. A linear sweep is triggered by signals from the Digital Analyzer, the length of sweep is related to a character in the 5- or 8-unit start-stop code. Means are provided to the operator to "blank" sweeps in a variable pattern, a single sweep may be followed by a blank trace for intervals up to six characters long or for an indefinite interval. Sweep rates accommodate signals from a nominal 37-, 45-, 50-, 61-, 74- or 150-baud circuit.

Automatic code and rate change is incorporated with the use of knob-controlled switches. A 5-unit code is normal, but grounding an external connection, through the selected circuit controls, causes the device to operate in an 8-unit code mode. This rate-code switch section is utilized in connection with the Digital Analyzer to change its operating rate.

The Distortion Pattern Generator provides transmission capabilities in a 5-unit, start-stop code at baud rates of 45-, 50- and 74-bauds. At the operators selection by a switch, reversals can be transmitted at baud rates of 37, 45, 50, 61, 74 and 150. An 80-character test pattern "THE QUICK BROWN FOX . . . . ," or the signal reversals may be selected by the operator by means of a switch on the front panel of the unit. The test pattern position allows space at the end of the test text for station identification by strapping at the time of installation. The character-by-character release of the test pattern, ex-



(Courtesy Stelma Inc.)

Figure 9. A-Scan Oscilloscope

cept reversals, is controlled by an external step signal. The distortion of output signal is determined by the setting of two switches on the front panel of the unit. One of these switches is incremented in steps of 10 from 0 to 40; the other from 0 through 9, in steps of one. This distortion may be introduced into the output signal in 1% steps from 0 through 49%. A switch selects the type of distortion introduced, either Zero Distortion, Marking Bias, Spacing Bias or Switched Bias.

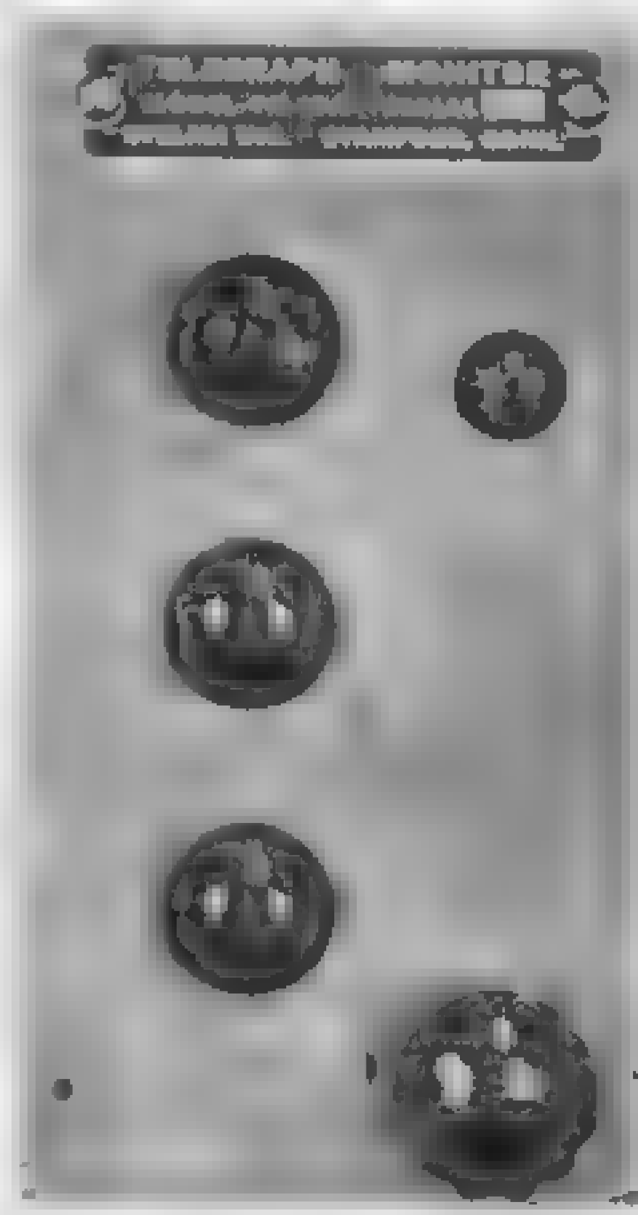
A telephone handset and dial for connection to the base exchange is provided on the right of the lower center panel.

As shown in Figure 6, 144 on-line monitor appearances are arranged across the console in the upper panels. These appearances, arranged in nine horizontal rows of sixteen lamp-switch groups, provide the indication for the electronic on-line monitor facility. The On-Line monitor, shown in Figure 10, is an electronic device which may be manually set to cause an alarm, at its appearance in the console, when its assigned circuit exceeds the limitation. The settings indicate the percent distortion to be measured in any signal element of a character, coupled with a certain number of "hits" in a preset three-minute interval. The baud-rate of the circuit must also be set.

Each group of channels in Figure 6 appears as two rows of eight push-button switch assemblies on either side of two push-buttons above a single push switch. All sixteen vertical columns of HIT-N/T and REV. LOGIC push switches function individually and are identical in operation. When a channel, which is being monitored by an on-line monitor, exceeds the predetermined distortion-time ratio set by the controls the top light in the upper switch assembly lights up behind the HIT screen. This alarm indication will normally cause the operator to initiate a procedure to examine the incoming signals in the BLACK area prior to "calling in" the distant terminal. Under certain conditions, if the operator wishes to re-examine the electronic monitor indication, the HIT-N/T push switch can be operated. This is a momentary contact switch and will return to normal when released. This action resets the monitor which will again alarm when the distortion-time ratio is exceeded.

Certain circuit conditions require an examination of the circuit for the presence of continuous reversals, or repetitive transitions. The electronic on-line monitor may be set up to give an alarm for the loss of reversals which will cause the upper push switch to light behind the N/T (No Transition) screen. This indication of No Transition shall cause the operator to initiate immediate steps to determine the cause either at the distant end, or within the station's receiving facilities.

A circuit found to be bad, or deteriorated beyond acceptable limits is removed from the normal traffic assignment according to standard procedures. A continuous test from the distant-end pattern generator should be requested, and the



(Courtesy Stelma Inc.)

Figure 10 On-Line Monitor

circuit observed by its electronic monitor, which is set to indicate when the distortion-time ratio falls within the acceptable limits. This is an indication of conditions which are opposite from the normal mode of on-line monitor operation. The ability of the monitor to indicate this condition is established by depressing the REVERSE LOGIC button which will light yellow when this condition is applied. The appearance of the red HIT light in combination with the yellow REVERSE LOGIC light indicates that a circuit failure has been recognized and is being electronically checked to determine when the circuit is again capable of handling traffic. When the faulty conditions have been corrected, the monitor releases thus turning out the HIT light and again sounding the common alarm to alert the operator to the new condition. When this occurs, the REVERSE LOGIC push switch shall again be operated returning the on-line monitor to its normal mode of operation.

The group control switches are centered between the two sets of individual channel push switches on Figure 6. These controls are for LAMP TEST, GROUP RESET and ALARM DISABLE.

When an entire group is affected by some transmission failure, all HIT lights for the group will be lighted simultaneously, and may be extinguished and reset by depressing the momentary contact GROUP RESET push button. This action resets all on-line monitors associated with the group.

If the alarm condition continues, and the audible and visual alarms of the common alarm facility are required to indicate failure of other channels, the ALARM DISABLE push switch for that group switch shall be depressed freeing the circuits. The push switch will light red when operated.

The momentary contact LAMP TEST push button will cause all lamps in the HIT-N/T push switches to be lighted. Failure of one lamp to light indicates a faulty bulb.

All of these monitor appearances operations are capable of being "multipled" between all consoles so that any operator may initiate or terminate the above steps.

A common alarm is provided on the Quality Control Console to give an indication of equipment failures in the various facilities of technical control responsibility area. These alarm lamps are located in the upper row of the top center panel with the audible feature directly behind the center grille.

Each lamp assembly is capable of indicating two separate alarm conditions because of the divided screen. Twenty visual alarms are provided. One audible alarm is provided for all visual indications and is controlled by means of the toggle switch labeled AUDIBLE ALARM. Three audible alarm conditions are possible:

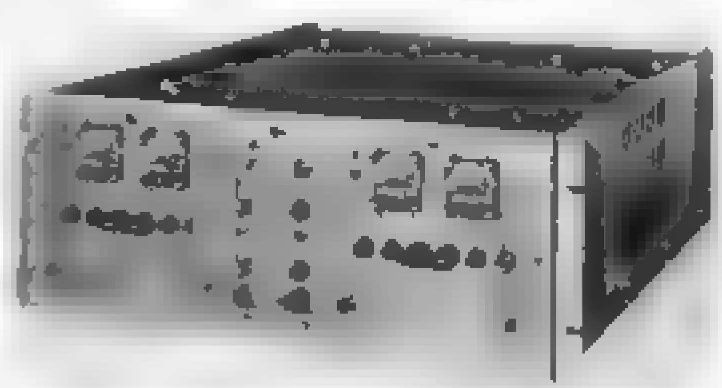
(a) With an operator at the console, the switch is set to the right ONE SHOT position. The chime will sound once for each equipment failure, but the indicator light will remain lighted.

(b) When one operator is serving more than one console, the switch is set to the left, CONT. position. The chime will sound, continuously at approximately four second intervals.

(c) The audible alarm may be turned off by placing the switch in the middle, OFF position. This is an unnatural condition, and so the OFF lamp lights red.

Centralized Maintenance

Maintenance and logistic support were considered as one of the major problems of providing the new Technical Control Facilities. Common apparatus was employed wherever possible. For example, all transistor circuits are powered from a



(Courtesy Stelma Inc

Figure 11 Dual Power Supply

common 15-volt rectifier In rack assemblies, this rectifies appears in tandem, as shown in Figure 11, with an automatic transfer to insure uninterrupted power These units switch on failure of the working power supply without measurable effect on the apparatus. When failure occurs, the common alarm panel at the control console immediately notifies the controller of the fault, and he has communication with the maintenance section via the intercom. Single power supply units are employed in the monitor teleprinter and quality control facilities where failure cannot interfere with through circuit operation. Similarly the time base generator, shown in Figure 12, used to set all apparatus to the various baud rates is common on all rack assemblies. This also has an automatic fall back with common alarm fault indication.

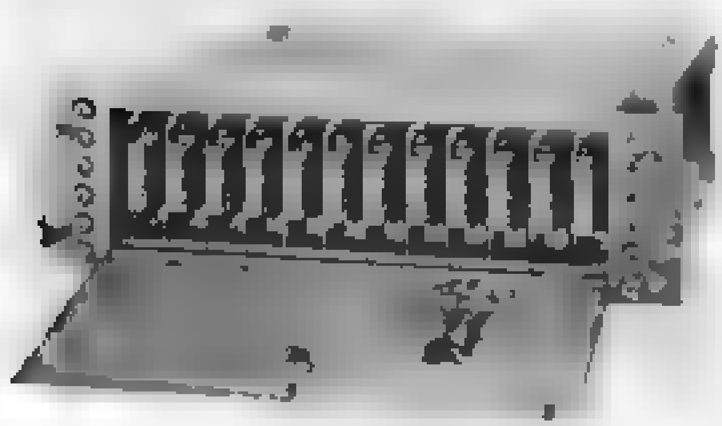


Figure 12. Dual Time Base Generator

To test the multitude of pieces of new apparatus, a Maintenance Test Bench, shown in Figure 13, was provided for the centralized handling of all faulty equipment. Each type of equipment is provided a test position under actual circuit conditions. Faulty equipment, patched into panels with extension cords can be tested and compared against known good apparatus by moving a switch to the appropriate position. A convenient push-button panel beneath the meter and scope, make possible most test procedures and measurements by pressing a button. Other test arrangements are possible by patch cords in the jack field. Of course, no equipment can replace the intelligence of a good maintenance man in localizing component failure, but with this test console, the equipment can be laid open on the bench and studied at length

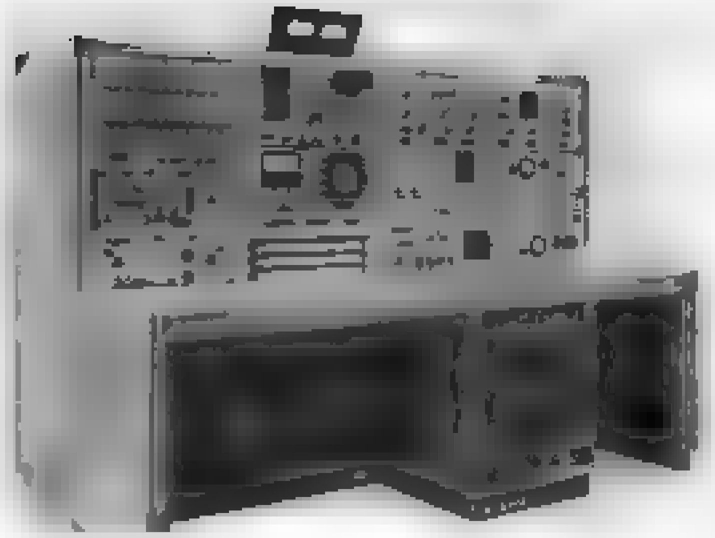


Figure 13. Maintenance Test Bench

Quality control and continuity of service are the predominant aims of the channel and technical control facilities section of the AIR FORCE COMMUNICATION SERVICE. It is their duty to maintain traffic of all classifications 24 hours a day, or to account for its outage. The burden of this responsibility can only be assumed by the operator, but the equipment provided him as described in this article attempts to make his work easier

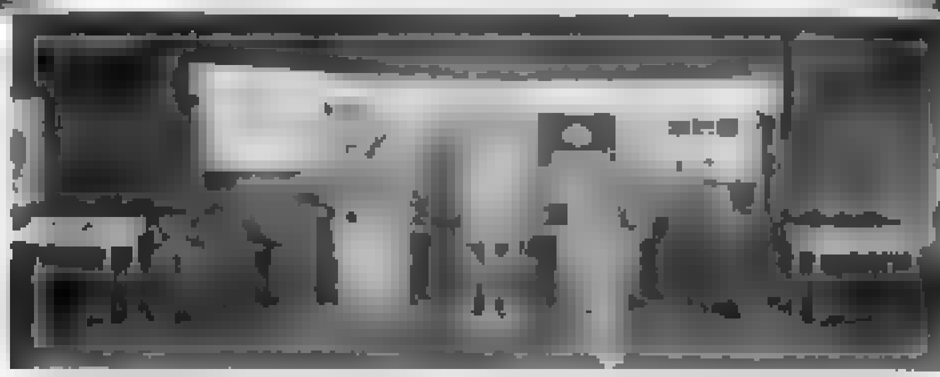
Note: Subsequent to the installation of the Findamatic unit, the rapid and unforeseen growth of traffic load through the Tech Control centers has made these units obsolete. Proposals are presently being studied to provide an entirely different concept of automatic baud rate setting and channel indication.

A biographical sketch of the author appeared in the January 1962 issue of the Western Union TECHNICAL REVIEW

Western Union "ON REVIEW"

Scenes from the Western Union Stockholders Meeting
Western Union Lobby, April 11, 1962

"CONQUEST IN COMMUNICATIONS"



Voice Data Systems
Weatherfax Systems
PATS
Bomb Alarm Display System 210-A

Book Review

Cost Reductions in Wire Communications, by Roy Stone, published by The Christopher Publishing House, Boston 20, Mass. Revised Edition 1959 (350 pages) Price $10.00

This book has been written primarily for the large user of communications, both record and voice. The major portion of the book, however, is devoted to the voice field and Bell System practices. Services offered by Western Union and the Bell System are described in considerable detail. Illustrations and considerable pricing data are included. Descriptions of the various types of Bell System switchboards are included.

Reading of this book gives the reader a very good comprehension of the equipment and services offered by the Bell System and helpful hints as to what to specify when ordering equipment which provides the best service at the lowest cost. A comparison of the advantages and disadvantages of PAX (Private Automatic Exchange) equipment and the use of long tielines for interconnections of PABX (Private Automatic Branch Exchange) equipment is included.

Our recent entry in the voice and voice-data field should make this book of special interest to Western Union personnel, especially those in the commercial area.

—A. F. Connery

J. H. HACKENBERG and F. L. O'BRIEN, Facsimile Division

Recording on TELEDELTOS* Electrosensitive Paper — Types L48 and L39

Some years ago an article about the development of Western Union's "TELEDELTOS" was published under the title, "Electrosensitive Recording Paper for Facsimile Telegraph Apparatus and Graphic Chart Instruments."[1] That article pointed out the need for a fast, simple and inexpensive record sheet for recording facsimile telegrams, and showed how this dry conductive paper was produced. It also described its characteristics, some of its advantages over electrolytic papers and a few of its applications. The article indicated that the characteristics could be changed by altering the amount of conducting material dispersed throughout the paper fibres in the "beating" process.

At that time two types of base stock were used in the production of TELEDELTOS one of which had a greater amount of conducting material dispersed throughout the fibres. TELEDELTOS produced from this latter paper stock was designated as Type L39 (low resistivity) — whereas TELEDELTOS made from stock having the lesser amount of conducting material was designated as Type H39 (high resistivity).

Over the years a number of changes have taken place in the development and production of TELEDELTOS. High resistivity paper stock is no longer used. Type H39 TELEDELTOS had no fundamental advantages over Type L39. On the contrary, it had a big disadvantage, because a higher marking voltage was required.

Another type of TELEDELTOS, utilizing the low resistivity base stock, was developed. This was designated as Type L48. This type of paper employs a different electrosensitive surface, which is brighter in color. Type L48 paper is used in many different types of Western Union facsimile recorders, which operate at stylus-to-paper speeds ranging from 18 inches per second to 240 inches per second.[2] TELEDELTOS Type L48 is also used in graphic chart recorder applications but some manufacturers of these instruments prefer Type L39 which has certain desirable characteristics for low-speed operation.

From time to time information bulletins on TELEDELTOS have been prepared, as guidance for instrument designers who wished to use TELEDELTOS as their recording medium. The most recent of these was issued in April 1959 and entitled "Recording on TELEDELTOS."[3] This bulletin combined, into one pamplet, the most important data from previous information bulletins. It also provided, for the first time in chart form, information about the electrical characteristics of Type L48 TELEDELTOS. The data for these curves were obtained from reports of laboratory tests dating as far back as 1954.

However, because a number of changes have been made in production methods since some of these tests were made, it was recently decided to conduct a coordinated series of tests with the express purpose of obtaining information to be used in preparing a revised and up-to-date bulletin covering both L48 and L39 TELEDELTOS. This article can therefore be considered as superseding the April 1959 bulletin and all earlier bulletins.

TELEDELTOS, Types L48 and L39, is a dry, electrosensitive recording paper consisting of a carbon-filled (conducting) base paper coated on the front surface with a lacquer-bound, light-colored pigment. TELEDELTOS changes color under the influence of electrical energy, from a light shade of gray to darker shades of gray or black, depending upon how much energy is applied.

The coating is very thin and somewhat porous so that the black paper tends to show through thereby giving the unmarked surface a light gray color. The reverse side of the black paper is usually coated with a lacquer-bound aluminum pigment to repel moisture and improve the appearance. The coated paper is approximately 0.0030″ to 0.0036″ thick and quite

* "TELEDELTOS" is a registered trademark of The Western Union Telegraph Company

stable dimensionally. Changes due to humidity are less than those for the paper stock used for telegraph blanks, forms, teleprinter rolls, etc. TELEDELTOS is not affected by light or by temperature changes normally encountered in handling or storage.

Recording Process

Recording on TELEDELTOS can be classified generally as an electrothermal process, although this is not the only action taking place. Several factors are involved in the recording process. They vary in degree depending upon how much electrical energy is applied. Among these factors are: (a) physical displacement of black carbon particles from the base paper through the porous layer of pigment to the surface, (b) partial-to-complete decomposition of the electrosensitive coating with a black decomposition product appearing on the surface, and (c) partial-to-complete removal of the coating exposing the black paper stock. The recording action is essentialy instantaneous and is permanent. No processing of any kind is required and no significant dimensional changes take place during the recording.

How Energy Is Applied

The electrical energy is usually applied between a metal stylus moving lightly over the electrosensitive coating and a metal platen or drum with which the back of the paper makes good contact. Since the paper is conducting, the platen making contact with the reverse surface need not be directly behind the stylus if other provisions are made to maintain suitable stylus-to-paper pressure. The contact with the reverse surface should not, however, be more than a few inches away from a point directly behind the stylus. If multiple styli are used, care must be exercised to minimize the mutual coupling through the sheet resistance of the paper.

In those applications where the paper is supported a short distance away from the stylus path, the stiffness of the paper provides suitable stylus-to-paper pressure. However, under such conditions it should be noted that the paper has a tendency to warp or *curl away* from the stylus in large areas of dense marking. It is generally preferable to have a solid metal backing directly behind the stylus where large dense areas are to be recorded. A helix-and-bar arrangement can be used but care is necessary to prevent excessive scraping of the electrosensitive surface. (See Section on STYLUS MOUNTING.)

Stylus Size and Material

Because there is a certain "graininess" in the surface texture of the base paper of TELEDELTOS (as there is in varying degree in all papers), the electrosensitive coating will vary in thickness over the sheet, being thicker in the "valleys" and thinner on the "hills." The breakdown voltage will vary therefore from one minute area to another. If a stylus having a large area in contact with the paper surface is employed, so that it spans a number of these "hills" and "valleys," marking will take place at the point of least resistance — that is, where the coating is thinnest — and a part of the area under the stylus may remain unmarked. The use of a large stylus — of the order of 0.030" to 0.050" in diameter — will therefore not produce a wide mark but will tend to produce a wavy or irregular one. Suitable sizes for wire styli are from 0.006" to 0.015". Any conducting material may be used but steel music wire or hard-drawn tungsten have been found well suited to withstand the friction, erosion and heat in most applications. Hard-drawn tungsten wire of 0.008" or 0.010" diameter is commonly employed in facsimile equipment used for the reproduction of documents, maps and drawings.

Size of Mark

The size of the mark made by the stylus will vary somewhat with the amount of current passing through the paper. In any case and regardless of the size of the stylus, it will not be much larger than 0.012". If a wider mark is desired it has been found expedient to oscillate the stylus in a direction perpendicular to the

normal stylus path at a rate high enough to give the appearance of a single broad mark. The width of the mark can be varied by adjusting the amplitude of the stylus oscillations.

Stylus Mounting

A flexible or resilient contact between stylus and paper is a prerequisite to satisfactory recording. If a fixed platen is employed directly behind the stylus, then the stylus must be flexibly supported with some form of spring providing uniform stylus-to-paper pressure. If the stylus is fixed, then the paper must be flexibly supported either with a leaf spring or springs or by utilizing the stiffness of the paper itself in such a manner that uniform stylus-to-paper pressure is maintained. Although it is possible to obtain satisfactory recording with the stylus perpendicular to the paper surface, it is preferable that it be tilted slightly from the perpendicular so that it presents a trailing edge to the paper. In this manner any tendency to scratch or gouge the electrosensitive surface is minimized. In any case it is desirable to "hone" a fresh stylus with extra fine emery cloth or "crocus" cloth to prevent scratching which might otherwise occur until the sharp edges have been worn away. It is also desirable in preparing tungsten wire styli to shear the wire to length rather than to use wire cutters (which mash the wire and leave a knife edge) Thus, the "honing" or "wearing-in" needed to remove the sharp edges is minimized as is the tendency of this type of wire to splinter.

Stylus-to-Paper Pressure

The most desirable stylus-to-paper pressure will generally be the lightest one at which uniform pressure can be maintained, less power being required to produce a given density of mark at lighter pressures. At low stylus-to-paper speed, pressures as low as one or two grams may be used. As the stylus-to-paper speed is increased higher pressure is required to maintain the stylus and paper in intimate contact. Pressures as great as 25 grams may be employed. However this is generally undesirable because of the greater power required to mark and because the electrosensitive surface may be either scratched or polished, tending to reduce the contrast between marked and unmarked areas.

Where dense recordings are to be made at low stylus-to-paper speeds somewhat higher pressures, than the minimum, will be required to prevent the accumulation of a residue on the end of the stylus. Decomposition products form a small, hard mass which may tend to build up on the end of the stylus. This can result in variations in the density of the recording and deviations in the position of the recorded lines which may be objectionable where areas composed of closely spaced lines are recorded. At higher speeds this effect is generally not present because the higher pressures usually required to maintain contact between the stylus and paper prevent the residue from adhering to the stylus or cause it to be dislodged promptly

Marking Circuit

The dynamic resistance of TELEDELTOS includes these major factors:

(a) Resistance of the electrosensitive coating,

(b) Contact resistance between the stylus and the coating,

(c) Ohmic resistance of the base paper.

Before the electrosensitive coating breaks down its resistance is relatively high, but after breakdown it becomes quite low even when recording low-density marks. The coating resistance therefore influences the design of marking circuitry because of the breakdown threshold voltage. Because the electrosensitive coating varies in thickness, from one minute area to another, the breakdown threshold voltage also varies from point to point across the sheet. (See STYLUS SIZE AND MATERIAL.) It is necessary therefore that the open circuit supply voltage be substantially higher than the actual voltage drop across the paper during recording to insure continuity of mark. It is generally desirable that the supply voltage be at least twice the

highest stylus voltage required during recording.

The contact resistance depends upon the surface texture, the condition of the stylus face which touches the paper (how well it is "honed"), the stylus-to-paper pressure, and the stylus-to-paper speed. At high speeds the contact resistance becomes the major factor in the over-all dynamic resistance. The ohmic resistance of the base paper is substantially constant under most recording conditions. However, if the temperature of the area under the stylus rises unduly either because the current is not properly limited or because the relative motion of stylus and paper has ceased, the base paper may become carbonized, the resistance reduced and a hole may appear in the paper. It is important, therefore, to provide for removal of voltage from the stylus when the stylus is at rest and to provide adequate current-limiting resistance in the marking circuit especially at low stylus-to-paper speeds. In this connection it should be noted that for many chart recorder applications a mark of 50 percent density is quite satisfactory. This can be obtained with about half the current required for an 80 percent density mark.

Regardless of the stylus-to-paper speed it is generally undesirable to depend upon the paper resistance alone to limit the current, for the reasons outlined above. It is desirable, rather, to employ circuitry which provides a fairly constant current through the paper. This may be achieved by using a voltage, several times the value actually required for marking, and a series resistor, or by using a high-impedance source. Vacuum tubes are particularly well suited to supply the marking potential because of their relatively high impedance. In the design of equipments in which the stylus-to-paper speed varies over a wide range, it may be desirable to include, in the marking circuitry, provisions for varying the series resistance, source impedance or applied voltage so that the density of mark remains substantially constant. In recorders where the line feed per scan is less than the stylus diameter (so that the recorded lines overlap), the effective paper resistance is somewhat lower than would be the case, where the recorded lines are isolated or just touching each other.

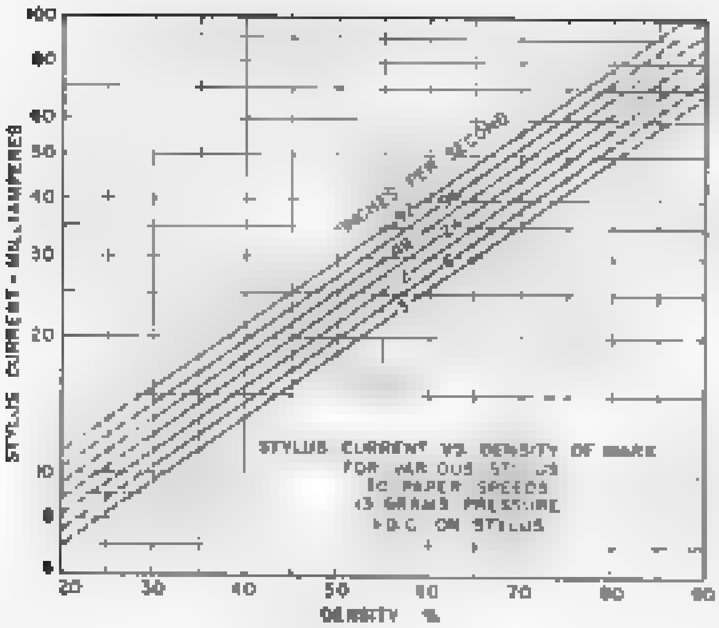
Polarity

Recording with positive polarity on the stylus usually is preferred because slightly less power (5 to 15 percent less) is required. In general, the difference will be greatest at light stylus pressures and very little at high stylus pressures. Because it is generally preferred, all of the characteristic curves shown in Figures 1 through 6 covering Type L48 TELEDELTOS are for positive polarity on the stylus. Marking with negative polarity on the stylus will generally result in a continuous line being somewhat thinner but of more uniform structure (less graininess) than with positive polarity on the stylus. The fact that the line is thinner causes the density of a recorded area (consisting of a group of parallel recorded lines) to be less with negative polarity on the stylus than with positive polarity for the same power. If the recorded lines are just touching with positive polarity on the stylus, there will be narrow strips of unmarked TELEDELTOS between the recorded lines with negative on the stylus. If there are narrow strips unmarked with positive on the stylus, the unmarked strips will be wider with negative on the stylus. In any event the average density of an area will be lower.

With negative polarity on the stylus, the accumulation of residue at low stylus-to-paper speeds (referred to under STYLUS-TO-PAPER PRESSURE) is negligible. Thus in certain low-speed chart-recorder applications, where the stylus-to-paper pressure must be kept low, the use of negative polarity on the stylus may be desirable. Since the chart recorders of this type often use Type L39 TELEDELTOS current-density and voltage-density curves for both polarities are included for L39 paper, as shown in Figures 7 and 8.

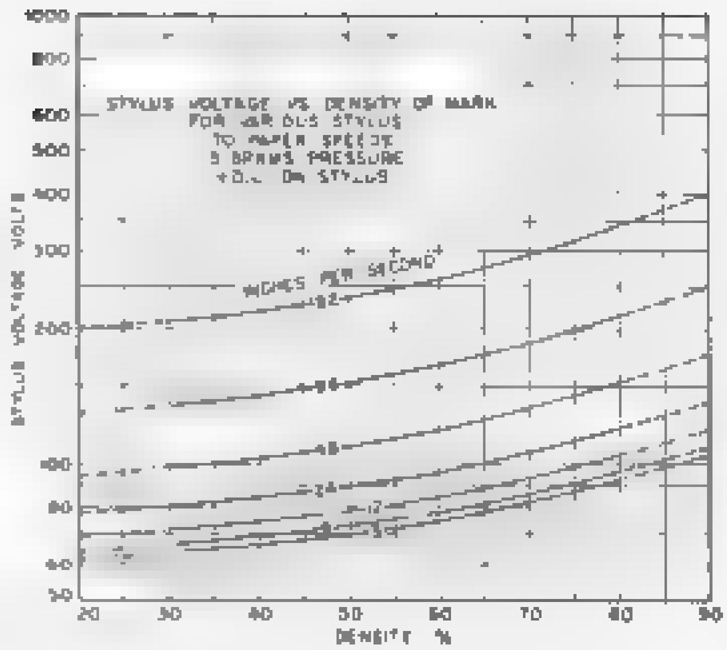
Alternating Current

Alternating current may be used for recording on either paper but if a continuous line is desired the frequency



Type L48

Figure 1 Current/Density Curves

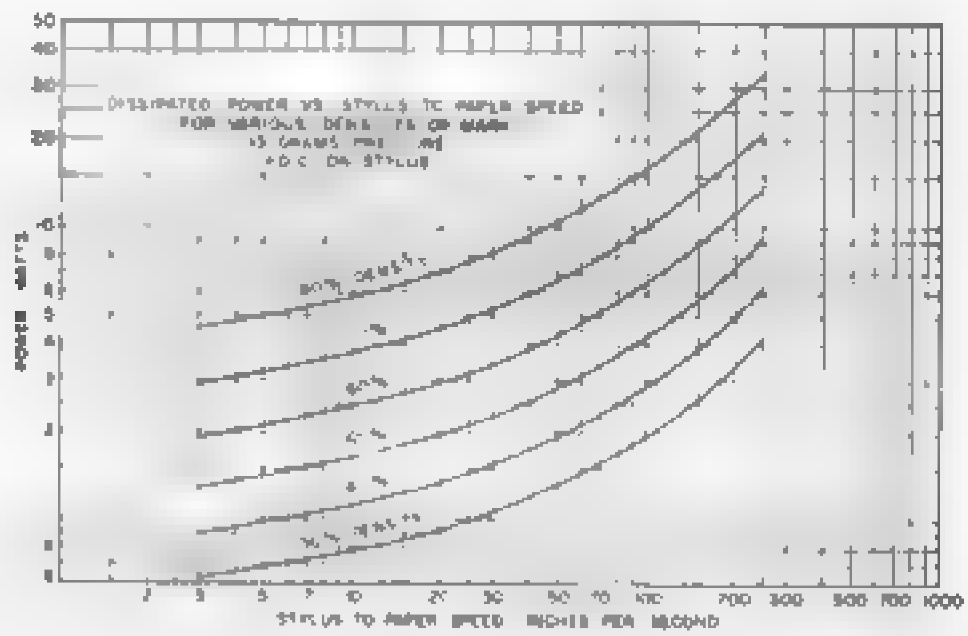


Type L48

Figure 2. Voltage/Density Curves

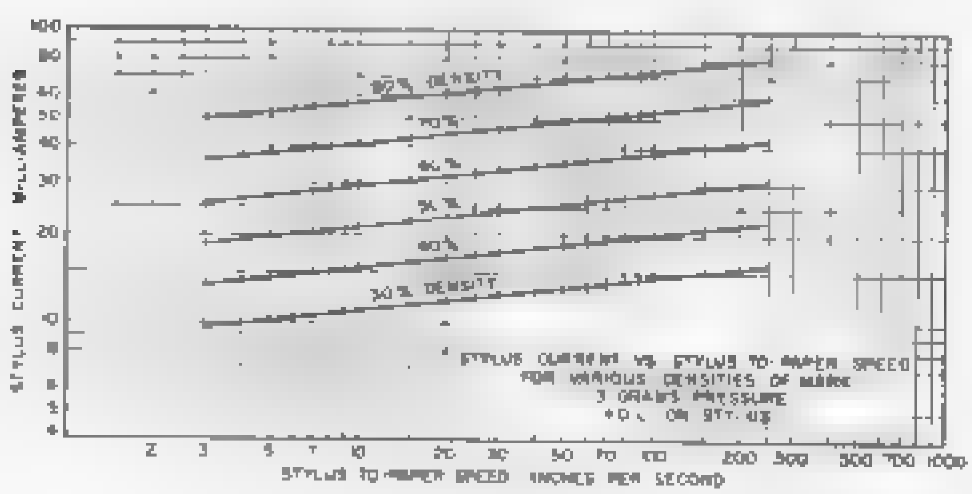
ype L48

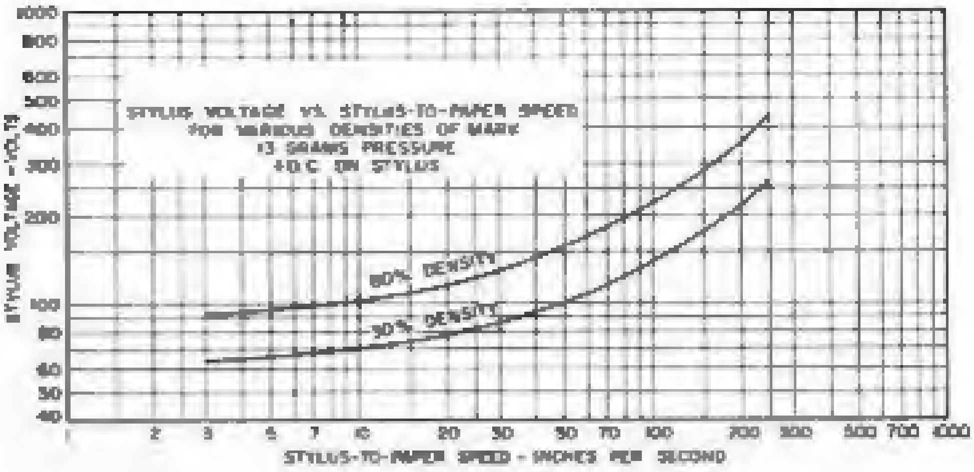
Figure 3 Power vs. Speed Curves



Type L48

Figure 4. Current vs. Speed Curves





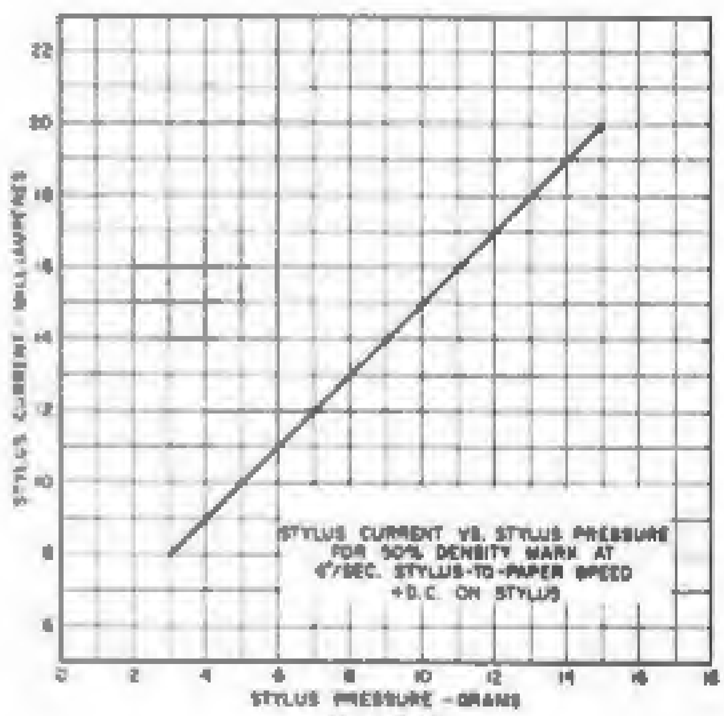
Type L48

Figure 5. Voltage vs. Speed Curves

employed must be sufficiently high in relation to the stylus-to-paper speed so that the half-cycle pulses do not appear as discrete dots or dashes. Also, for efficient operation, it is desirable that the source impedance match the paper impedance. Since the paper impedance varies with the density of the mark the impedance at maximum density is the figure commonly used for matching. Where it is desired to record graphic material having several density steps, it may be necessary to alter the linearity of the signal amplitude to compensate for the non-linear paper impedance in order to achieve the desired density linearity. This is usually accomplished in vacuum tube circuitry by utilizing tubes and circuit constants which provide the desired characteristics. For all practical purposes, the paper impedance can be considered as pure resistance for marking frequencies up to 50 kc. If the ratio of marking frequency (in cycles per second) to stylus-to-paper speed (in inches per second) is of the order of 100 or higher, the characteristic curves for both types of paper will be very much the same as those given for positive polarity direct current.

Tolerances in Characteristics

Although every step in the production of TELEDELTOS is carefully supervised, substantial variations in the basic current-density and voltage-density characteristics can be expected. These variations are of the order of ±15 to 20 percent for L48 paper. Although the same rigid quality controls are exercised in the production of L39 paper, the basic characteristics may vary as much as ±40 to 45 percent with positive polarity on the stylus and as much as ±25 to 30 percent with negative polarity on the stylus. Differences in formulation of the electrosensitive coating—primarily the use of an entirely different pigment—are responsible for the variations in characteristics being approximately twice as great in the L39 paper.



Type L48

Figure 6. Current vs. Stylus Pressure

Test Conditions

To obtain the data necessary for the preparation of the characteristic curves, tests were made of many samples taken from several manufactured lots of both L48 and L39 TELEDELTOS. Recordings were made on a simple drum-type recorder using a tungsten wire 0.010" diameter as the stylus with a pressure of 13 grams, except as noted. Since it is impractical to measure the density of a single

isolated recorded line, at least 25 lines, spaced 100 lines to the inch, were recorded in each test to obtain an area at least 1/4" wide from which density measurements could be made. This stylus material, size and pressure, and the spacing of 100 lines to the inch were chosen because they are commonly used in facsimile equipment designed for the reproduction of documents, maps and drawings.

If a stylus of 0.008" diameter had been used with correspondingly closer line spacing, slightly less current would have been required to produce each level of density. Had a 0.012" stylus with correspondingly coarser line spacing been used, slightly more current would have been required to produce each level of density. Because of the variations in thickness of the electrosensitive surface from point to point across the sheet, low-to-medium density recorded areas will contain many minute unmarked areas. If a recorded area is retraced, more of these unmarked areas will break down and the average density will be higher. For this reason, if the recorded lines overlap (as would be the case where the stylus diameter is greater than the line-to-line spacing), somewhat less current would be required for the lower-to-medium density recordings but little or no reduction would be found for the greater densities. The over-all shape of the characteristic curves would therefore be somewhat different from that of those shown here.

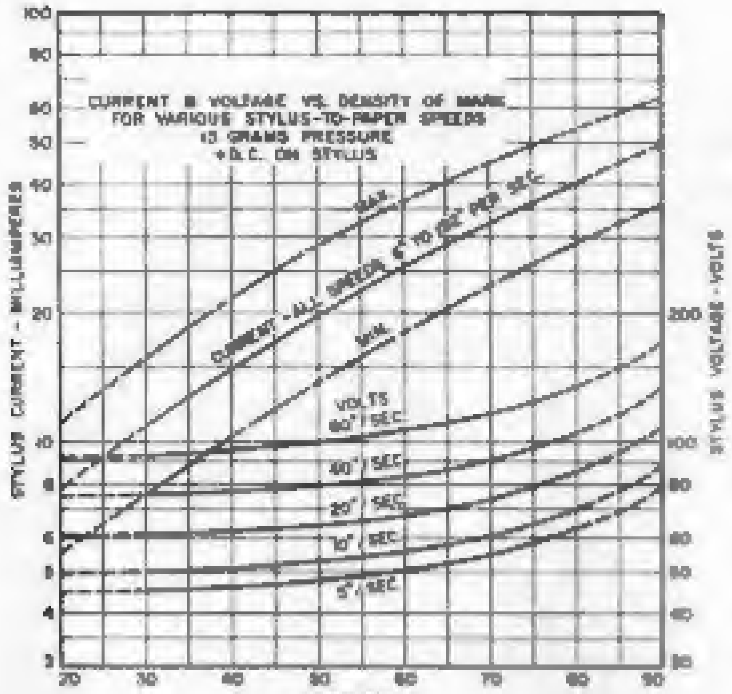
Effect of Stylus Pressure

If the recordings had been made with a different stylus pressure, a substantial difference in the current required to produce each density would have been noted. However, it would have been difficult to maintain intimate contact with the electrosensitive surface at the maximum speed used in these tests with a lower stylus pressure. Figure 6 shows that the stylus current required to produce a 50 percent density mark varies linearly with stylus pressure between the limits of 3 grams and 15 grams. Outside these limits some deviation from linearity may be expected. A similar relationship can be expected for other densities of mark and for other stylus-to-paper speeds. At the speed chosen for this test (6 inches per second) there is very little variation in voltage through this range of stylus pressures. However, at higher speeds significant voltage variations may be expected because larger variations in contact resistance are likely to exist.

The test recordings were made with direct current and with positive polarity on the stylus, except as noted. The stylus current and voltage drop across the paper were measured for several densities of recording on each paper sample and repeated for a number of recording speeds. Density measurements were made with a reflectometer by comparing the light reflected from the recorded areas with standard Welch Reflectometer "tone chips." The reflectance of each recorded area is expressed as a percentage of the light reflected from the unmarked sheet. The density figure is then obtained by subtracting this percentage from 100. Current-density and voltage-density curves were then plotted for each sample. Afterwards values taken from these curves were averaged and a composite series of curves plotted. These form the basis for the smoothed and somewhat idealized curves of Figure 1 and Figure 2. From these curves information was obtained from which the curves of Figures 3, 4 and 5 were plotted.

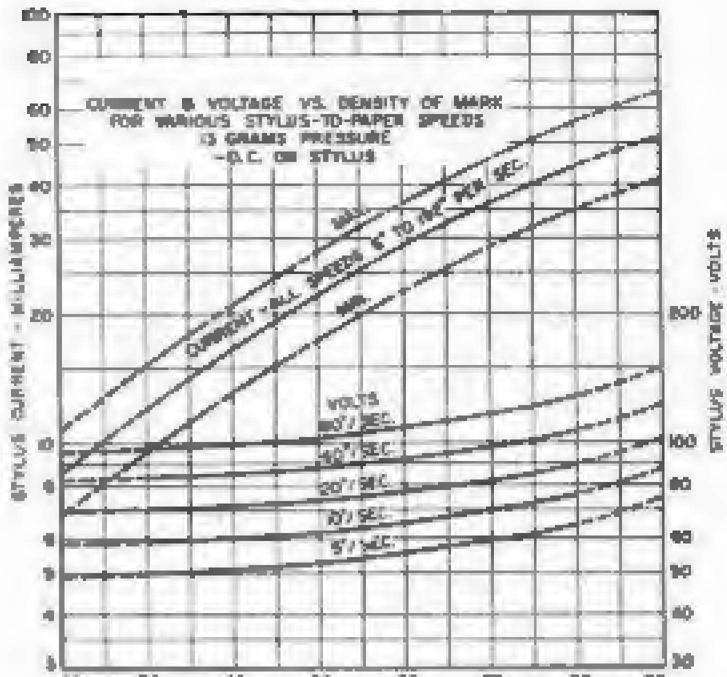
Type L39 TELEDELTOS

The shape of the current-density curves for Type L39 TELEDELTOS can be expected to differ somewhat from those for the Type L48 paper because of the different pigment used in the electrosensitive coating. It may be expected that slightly higher currents would be required at higher speeds to produce a given density of mark, as is the case with L48 paper. However, there seems to be even less difference in current for different speeds than that with L48 paper and for all practical purposes between the limits of 3" per second and 160" per second the difference in current required is negligible. In any event the variation in characteristics beween different L39 paper samples is so great as to completely mask the variations



Type L39

Figure 8. Current/Density and Voltage/Density Curves (negative polarity)



Type L39

Figure 7. Current/Density and Voltage/Density Curves (positive polarity)

in current due to speed. For this reason it was felt undesirable to attempt to show a group of current-density curves for the L39 paper. The curves of Figures 7 and 8 were obtained in the same manner as those of Figures 1 and 2.

Figure 1 shows that the current-density relationship for L48 paper is an exponential one, the curves being reasonably linear (at least between the limits of 30 percent and 80 percent density) when plotted on semi-log paper. Outside these limits the curves are shown as dashed lines because there is considerable irregularity in these regions. Below 30 percent density the current will be an average between moments of "mark" and "no-mark" and the voltage will be an average between "load" and "no-load" conditions making accurate measurements difficult. Above 80 percent density, increasing the power into the paper does not bring a corresponding increase in density but instead tends to produce increased accumulation of residue on the tip of the stylus making accurate voltage and current measurements difficult. The current-density curves for different speeds are closely bunched, only about 8 percent more current being required each time the speed is doubled. This current increase with speed is reasonably linear between the speeds of 3 and 250 inches per second as will be seen more clearly in Figure 4. The voltage drop across the paper does not increase much with increased density, as shown in Figure 2. The increase in voltage drop from 30 percent density to 80 percent density is only 45 percent at low speeds and 65 percent at high speeds. The voltage drop across the paper rises, however, with increased speed at a rate which is approximately exponential as shown in Figure 5. This is due largely to the effects of a rapidly rising contact resistance.

Figure 3 shows the power required for marking at speeds between 3 and 250 inches per second for various densities of mark. These are not meant to indicate the upper or lower speed limits of TELEDELTOS. Much lower speeds are common and recordings at speeds as high as 1000 inches per second have been made in the laboratory. Figures 7 and 8 include only 3 curves of current versus marking density for L39 TELEDELTOS. These curves are not as steep as those for L48 paper and they are not as straight (plotted on semi-log paper). The current required for a 30 percent density mark, using L39, is about the same as that with L48 paper; but for an 80 percent density mark only about two-thirds as much current is required as is required for L48 paper. The solid curve

in each case is the average curve for all samples; the dashed curves indicating the extremes of variation which might be expected between samples taken at random from various manufactured lots.

It will also be noted that the voltage drop across the paper is less for the L39 paper than for L48. The voltage-density curves are flatter (at least at the lower densities) than those of L48 paper, there being very little difference in voltage drop up to 50 or 60 percent density. At the mid-density area (40 percent to 60 percent) where the difference is greatest the marking voltage for L39 paper is only about two-thirds that of L48.

Applications

A few examples of the applications of TELEDELTOS in graphic chart recorders were cited in the early article.[1] Today, there are literally hundreds of different types of graphic chart instruments employing TELEDELTOS. They are used in school and college laboratories, in research laboratories, in hospitals, in commercial and industrial organizations and government agencies.

These instruments are used to record our heart beats, our brain functions, our reactions to nervous stimuli, to record the progress of laboratory experiments of all kinds, to record temperature, pressure, velocity, voltage, current—indeed practically every quantity man has learned how to measure. They record the flow of industrial processes, indicating the time and duration of interruptions; they record the flow of traffic on railways and highways; they guide ships into harbor by recording the depth of the bottom and the presence of other craft; they record the presence of aircraft in radar-surveyed areas, they even record the presence of fish for commercial and amateur fishermen. Any attempt to list the organizations which utilize TELEDELTOS in their research or in laboratory or commercial graphic recording devices would become a "who's who" of American business and industry and is beyond the scope of this article.

A somewhat unusual application for TELEDELTOS recording paper Types L48 and L39 is found in analog field mapping.[4] In this application its advantages stem from the fact that it is a dry medium, safe to use because of the low voltage requirements, convenient because low current is required, and has no polarity limitations. Furthermore, it is relatively inexpensive both for the material itself and for the electrodes, and extremely stable dimensionally.

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3. "Recording on Teledeltos," an information bulletin compiled by T. F. COFER, R&E, and issued by the Marketing Dept., *Western Union Telegraph Company*, April 1959. (Out of print.)
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Reprints of this article and of the article of reference [4] above may be obtained from The Western Union Telegraph Co., Marketing Dept., Govt. and Contract Sales, 60 Hudson St., New York 13, N. Y.

Mr. F. L. O'Brien (left) and Mr. John H. Hackenberg (right) of the Facsimile Division authors of the above article. Their biographical sketches appear on the opposite page.